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American Welding Society

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JOURNAL

of the

AMERICAN WELDING SOCIETY

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Welders Join with Steel Treaters for Exhibition

In accordance with the precedent established last year, the American Welding Society joined with the American Society for Steel Treating in a joint exhibition of welded products and welding apparatus and supplies. This exhibition will be held in Philadelphia at the time of the fall meeting of the American Welding Society and the annual meeting of the American Society for Steel Treating, Oct. 8 to 12. Every effort is being made to insure the success of this exhibition and the fall meeting of the society. A record attendance is expected. A great deal of the exhibition space has already been sold.

Matters pertaining to the welding exhibition is in charge of an exhibition committee, consisting of Mr. C. A. McCune, chairman, and Mr. W. W. Barnes and Mr. J. W. Meadowcroft.

Officers for 1928-1929

The following nominations for officers for the year 1928-9 have been announced by the Nominating Committee:

For President

F. T. Llewellyn, U. S. Steel Corporation, New York, N. Y.

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Electrical Engineers Hold Welding Session

In connection with the annual meeting of the American Institute of Electrical Engineers, a welding session has been scheduled for Friday afternoon, Feb. 17, 2 p. m., to which are invited all the members of the American Welding Society. The following are the scheduled papers: Effects of Surface Materials on Metallic Arc-Welding Electrodes, J. B. Green, Fusion Welding Corporation; Arc Welding—Influence of Surrounding Atmosphere on the Arc, P. Alexander, General Electric Co.; Arc-Welded Structures and Bridges, A. M. Candy, Westinghouse Electric & Mfg. Co.; Welding and Manufacturing of Large Electrical Apparatus, A. P. Wood, General Electric Co.

Michigan Engineering Conference Features Welding

At the Third Annual Conference of Michigan Engineers held on January 27 and 28 at the Hotel Statler, Detroit, one of the papers was devoted to the subject of welding, by W. Spraragen.

This conference is sponsored by the technical organizations, civic groups and universities throughout the State of Michigan. Over 700 engineers were present at the welding session.

Research in Industry

The emphasis that is being placed on the necessity of research is indicated by the following editorials taken from the Current Technical Press.

If the welding industry is to advance as rapidly as it has during the past few years, it must make research an important part of its activities.

The American Bureau of Welding, which is the research department of the American Welding Society, and which is responsible for the cooperative investigations in this field, will during the coming year, conduct investigational work on welded rail joints, welding wire, study of welds subjected to elevated temperature, fatigue strength of welds, effect of heat of welding on adjacent metal, welding as applied to structural steel, and welding as applied to welded pressure vessels. These investigations deserve the whole-hearted support of the industry and, in fact, must fail without such support.

Commercial Versus Theoretical Research

[*Reprinted from Jan. 14, 1928, issue Electrical World*]

Research has become a necessary auxiliary to management and operation in the industrial organism. More than a thousand companies have research divisions, 70 trade associations spend about $15,000,000 a year in research, 152 colleges spend about $1,500,000 for the same purpose, and several government departments participate. About $200,000,000 annually is now spent for research in this country. Electrical men have contributed greatly to the cause. Their industry is fortunate in that it deals with a new science which can be put to work only by the use of imagination and precision measurements. They have learned by experience that research is a profitable commercial activity and that it acts as the key to market supremacy. As a consequence research is an established auxiliary in all branches of the industry.

Commercial research should be divorced from theoretical research. They mix like oil and water. Commercial research should be tied directly to production and market objectives and must measure itself in dollars and in other commercial values. This class of research requires men who know manufacture and marketing as well as science. Their work must be focused on visualized objectives in the factories and on the properties. But general theoretical research should have no commercial ties. It is a job for scientists who sit on top of a mountain and try to pierce the unknown in every direction. These men are fact finders through the application of principles. Only general fields of science may be outlined for their guidance, and results depend entirely upon their individual limitations and upon interpretation of chance discoveries.

In the world of industry commercial research is needed by all groups and is an auxiliary to progress in every branch. But theoretical research is the true research and should not be placed second in any industry program. Each business should support some commercial research as part of its activities, but in addition industry should support theoretical researches. In the colleges an admirable atmosphere for the growth of this type of research exists, but they are too poor to do the tasks, and frequently they are too busy teaching to be concerned with research. Both the government and industry should study the research situation in order to provide means to place pure or theoretical investigation on an adequate basis. It only has permanent value and it deserves the utmost in co-operative support.

Structural Welding

[*Reprinted from Jan. 12, 1928, issue Engineering News Record*]

Though any one year's contribution to structural engineering growth is not easy to appraise, there are evidences of vigorous progress which indicate a virile substratum of engineering thought and initiative. Such was the activity in structural welding. It was marked by the construction of a number of industrial buildings, the largest a two-acre factory at Derry, Pa., completed late in the year. Another all-welded manufacturing building is now under construction in Philadelphia. Welding was promoted not only on the practical but also on the technological side, the latter largely through the influence of a research committee of the American Welding Society, whose final results are expected to give tangible data for structural design. Some important welded bridgework was also undertaken, including the reinforcement of a railway bridge across the Missouri

at Leavenworth, the addition of a second deck to the Susquehanna River highway bridge at Havre de Grace, and the construction of a skew railway truss bridge at Chicopee Falls. Somewhat related is the extending use of welded structural assemblages in place of heavy castings in machinery, on power shovels, trailers, engine and pump bases, and the frames of electric machines. Further, welded-joint pipe-line construction gained largely in use.

Scientific Development

(Reprinted from Jan. 12, 1928, issue *Engineering News Record*)

Though without marked outward incident, scientific advance through research has continued to play a prominent part in American industrial progress during 1927. Study of problems of quality, production and service increased principally through trade associations, which represent the cooperation of different concerns within a single industry. One of the year's new happenings was the organization of a research department by the United States Steel Corporation, specifically directed to scientific research as distinguished from practical investigation of the kind that the company had previously carried on. By this innovation one of the oldest fundamental industries took a step toward placing itself on a level with those newer industries—the chemical, photographic, and automobile—which have depended essentially on research for leadership.

Put Research Into Budgets*

Electrical development bristles with interrogation points whether viewed from the economic or the scientific side. The industry progresses through the application of natural laws to the needs of mankind by research workers and engineers cooperating for the common good. Every operating company is a potential laboratory as well as a commercial enterprise, and its research value increases with the years. In the past economic limitations have too often prohibited creative investigations on "bread-and-butter" properties, but a new era has dawned. Never have the American people been so aware of the value of research as today. Well-directed publicity has thrown open laboratory doors; medical schools and astronomical observatories are offering popular lectures upon their achievements, and trade organizations are touring electrical manufacturing plants and getting new conceptions of the equipment and personnel required by modern progress. The scientist and the engineer may look upon spectacular experiments and demonstrations for the edification of laymen as a species of vaudeville, but popular interest in electricity has been created in many ways and should be capitalized for the benefit of true research.

It is a safe estimate that a reasonable appropriation for research from now on in public utility budgets will receive the approval of the great majority of stockholders, and that the employment of more research ability even in some of the larger companies will not be questioned if the management takes this step with real vision. Out of daily routine come innumerable opportunities to investigate problems whose solution contributes to the enduring welfare of the industry and those whom it serves. Here is a brilliant chance for centralized management to win new laurels or for the single company to follow up leads hitherto blocked by lack of organization, funds or managerial sympathy.

*Reprinted from *Electrical World*, Dec. 10, 1927.

Obituary

Herbert Gordon Thomson, president of Anchor Post Fence Company, who died suddenly of heart failure in Grand Central Terminal, on January 11, was a son of the late Dr. William Hanna Thomson.

After graduating from Yale in the class of '93 Mr. Thomson began to develop the idea of the anchor post and to manufacture in Long Island City.

Soon larger manufacturing space was required and a factory was erected at Garwood, N. J. Later another at Cleveland, Ohio, and a new one containing about 100,000 square feet of floor area has just been added at Baltimore, Md.

He was also president of the National Fence Company of California and a member of the American Welding Society, as well as of the American Society for Testing Materials.

SECTION ACTIVITIES

Boston

The January meeting of the Boston Section was devoted to the showing of moving pictures entitled "Blue Center," the story of Roebling wire rope; and "Thermit Rail Welding," showing a method of joining track rails.

Chicago

The Chicago Section held its January meeting on the 6th in the rooms of the Western Society of Engineers. There were about seventy-five men present. A motion picture entitled "The Story of Steel," furnished by the United States Steel Corp., was shown, starting at 7:30.

Mr. C. H. Hollup of the C. H. Hollup Corp. spoke on "Appearances as a Factor in the Arc Welded Fabrication of Iron and Steel." This paper was very interesting and presented some very new ideas with reference to the fabrication of metals. Mr. Hollup had with him a set of specimens similar to those illustrated in the article and passed them among the audience for their inspection.

On February 3, the Chicago Section held a meeting at which were present 150 men. Two one-reel motion pictures were shown, entitled "Panama Canal" and "Making Mazda Lamps."

Mr. F. J. Maeurer, engineer for the Air Reduction Company, was the speaker of the evening and presented a very interesting paper entitled "Oxy-Acetylene Welding Light Gage Sheets by Simple Mechanical Methods." This subject was followed by a considerable discussion.

A Nominating Committee was appointed by the Chair, consisting of: Chairman, H. S. Card, Welding Engineer Pub. Co.; W. A. Slack, Torchweld Equipment Co.; K. R. Hare, C. H. Hollup Corp.; R. G. Mason, Santa Fe R. R. Co.; B. N. Law, Air Reduction Co.

This committee was instructed to prepare a slate for officers and directors for the ensuing year. As soon as this slate is available the Secretary will send out printed ballots and the results of this election will be announced at the meeting of the Section to be held April 6th.

Los Angeles

On January 26, the Los Angeles Section held its meeting. Mr. A. G. Bissell, general welding engineer of the Westinghouse Electric & Mfg. Co., and Mr. W. F. Barron of the Linde Air Products Co. were the speakers at this meeting. Mr. Barron talked on the Revised Air Pressure Safety Orders.

Philadelphia

The Philadelphia Section held its regular monthly meeting on January 16. Mr. D. M. Petty, electrical engineer, Bethlehem Steel Co., addressed the meeting on "Applications of Welding in the Steel Industry."

On February 20, the Philadelphia Section will hold its monthly meeting. The speaker of the evening will be Mr. G. L. Walker of Apparatus Research and Development Department, Air Reduction Sales Co. He will speak on "Cutting Cast Iron by the Oxy-Acetylene Process." Mr. Walker's paper is on the practicable application of the torch, rather than the theories that have been advanced in explanation of the process. He will undertake to acquaint those who are unfamiliar with cutting cast iron, or who have had rather indifferent success, with the methods of procedure by which it can be cut successfully. The paper will cover: The class of work in which the process can be applied economically; the selection of torch, tip and gas pressures; the adjustment of the flame; the manipulation of the torch.

Pittsburgh

On January 25, the Pittsburgh Section held a meeting. Mr. D. M. Sholley spoke on "Welding of Metals." This was an illustrated lecture covering thermit welding, welding of cast iron by all processes, non-ferrous welding, welding of pipe, shear blades, discussion of welding wire, welding structural steel and qualifications of welders.

New York

The February meeting of the New York Section was held on the 6th and was preceded by a dinner meeting of the Executive Committee at the Engineers Club. A three-reel picture on "The Story of Petroleum" was shown, starting at 7:30 p. m. This was a remarkable picturization of methods and processes used in the oil industry from digging the wells to transpor-

tation of the product and its utilization in industry.

Mr. F. C. Fyke, engineer of inspection, Standard Oil Co., presented an address on "Welding as Associated with the Handling of Petroleum Products." He described in detail the applications of welding in this field to pipe line and tank construction and their uses covering materials, design, testing the product and welders.

The second paper of the evening, "Procedure Control in Welding Pressure Vessels," was presented by Mr. H. E. Rockefeller, Engineering Department, Linde Air Products Company. Mr. Rockefeller gave an illustrated talk covering the results of a comprehensive series of investigations made by his company dealing with the proper methods of constructing pressure vessels.

Northern New York

A meeting will be held in Feb. 29 in the Rose Room at the Twentieth Century Restaurant, 147 Jay Street, Schenectady.

An illustrated talk on Unit Strength and Reliability in Structural Steel Welding will be given at 7:45 p. m. by Mr. F. T. Llewellyn of the U. S. Steel Corp.

A steak dinner will be served at 6:30 p. m.

At 2:30 p. m. an inspection trip will be made through the Schenectady Works of the General Electric Co. to see applications of the various forms of welding.

Those who wish to make this inspection trip will meet at the main gate house at 2:30 p. m.

Western New York

The Western New York Section held their regular monthly meeting on Tuesday evening, Jan. 17, at the Statler Hotel, Buffalo.

This was a joint meeting, being under the auspices of the American Society of Mechanical Engineers and the A. W. S., Western N. Y. Section.

The principal speaker of the meeting was Mr. W. P. Wooldridge, metallurgical engineer, National Tube Co., his subject being "The Arteries of Industry," illustrated by five reels of motion pictures, these pictures showing the manufacture of steel pipe, illustrating the various processes, from the mining of the ore to the final test, including the regular and slow motion pictures of the Bessemer and Open Hearth Processes, and the three processes of Welding—the Lap Weld, the Butt Weld, and the Hammer Weld, all of these being further illustrated by cross section of equipment used in the several processes, as well as the manufacturing equipment.

Through the courtesy of the E. I. DuPont De Nemours & Co., there were shown several reels of moving pictures of the construction of the subways of New York City, including the widening of streets in New York, showing this widening process as calling for the entire removal of entire five-story buildings, traffic being maintained at the street level, as well as construction work proceeding underneath the street level.

San Francisco

The January meeting of this Section was held on January 27. Two papers were read by Mr. C. E. Rhein of the Linde Air Products Company, on "Selection of Materials for Welding" and "New Shear-Vee Bronze Joint for Cast Iron Pipe." These papers were illustrated by slides.

Employment Service Bulletin

SERVICES AVAILABLE

A-68. Welder desires position. Have had four years' arc welding experience on heavy plate construction. Have also had three years' experience on light sheet metal with both oxy-acetylene and arc welding. Would prefer location in Western Pennsylvania or Ohio.

A-69. Welder desires position. Experience as acetylene welder in shipyard, foundry and production shops in New Orleans. Electric welder for General Electric at Schenectady plant; for B. M. T. repair shop, DeKalb and Seneca Avenues, Brooklyn; International Welding Co., Greenpoint, and at present have temporary employment as gas welder making ice machine equipment for high pressure work.

Welding of Power Plant Piping*

By A. W. MOULDER†

Scope of Paper

THIS presentation is intended to cover the subject as it relates to the fusion welding of power plant piping only and is not intended to relate to the forge or hammer welding process. The discussion is also based upon the use of the oxyacetylene rather than the electric-arc process. This is primarily for the reason that the former process is the one which has been found most practical for work of this kind, probably due to the fact that the welding of power plant piping is not a production problem, but rather almost every order presents somewhat different "cut and fit" problems. The ability of the same operator to use the torch for both cutting and welding has no doubt had a considerable bearing on the fact that this process has been the one most generally adopted for this class of piping work. Furthermore, our own reasearch work and most of the research work with which the writer is familiar and which deals with the particular problems involved has been in connection with the oxyacetylene process. It has been our experience, however, that where the electric-arc process has been employed by us, the same general methods of preparation of materials, training and testing of welders and testing of finished products have been likewise employed and as far as we have been able to determine without going into the same research work, with equally satisfactory practical results.

Advantages of Welding Power Plant Piping

The welding of power plant piping is unquestionably growing in favor steadily. There are a number of basic reasons behind this growth which, briefly, are as follows:

1. Elimination of screwed and flanged joints with resulting lower maintenance costs.
2. Lower first cost, especially where a multiplicity of connections are made to a pipe in a limited area such as in case of headers.
3. Decreased weights—especially where welded steel is substituted for large cast fittings.
4. Continuity of insulation is permitted by elimination of flanges, with resulting increased efficiency and decreased cost of insulation.
5. Improved service in erection, especially where field welding is employed and in overcoming the time required for the making up of "special" or odd shaped fittings.

All of the above advantages were, of course, recognized in the early days of pipe welding. The importance of power plant piping, however, in that a failure not ony endangers the life and limb of employees, but cuts off a most important service, has had a just deterring effect upon the growth of welding for this class of work as compared to its growth in other classes of piping work. A number of the more responsible concerns dealing in the fabrication and erection of power plant piping have been furnishing piping of this class for many years and the record

*Presented at joint meeting of Metropolitan Section of American Society of Mechanical Engineers and American Welding Society, Jan. 3, 1928.

†Heating, Power and Industrial Piping Division, Grinnell Company, Inc., Providence, R. I.

in connection with these materials has been so excellent as to gradually win over the confidence of engineers and purchasers until today welded piping is growing in use for power plants more rapidly than at any other period in its history. The writer has been unable to learn of any accident ever having been caused by a failure in welded piping made by any responsible pipe fabricating concern.

Our own concern has been fabricating welded piping for nearly eighteen years, and during that period has put into service hundreds of thousands of welds in steam pressure piping and without a single failure having come to our knowledge. Today it is not unusual to be called upon to fabricate welded piping for 400 lb. working pressure of superheated steam and total temperature up to 750 deg. Fahr. Therefore, I repeat that the record behind welded piping made under proper management

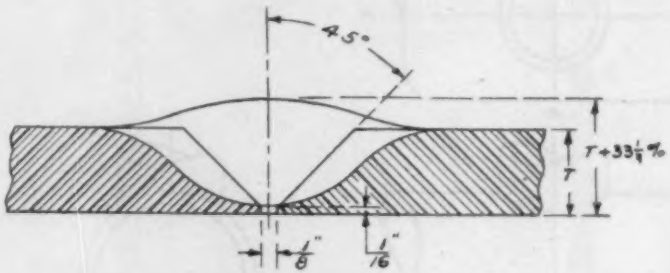


FIG. 1. MAKING A BUTT WELD

is responsible for its growth in favor more than any one of the apparent inherent advantages.

Factors Affecting Quality of Welds

On the opposite side, the question naturally arises, why hasn't welding of power plant piping grown to a point of the almost exclusive use to which its many advantages would seem to indicate it is entitled? The answer is today just the same as it was ten or fifteen years ago. What assurance has the purchaser that the welds are properly made? The answer to this has been written into your records many times, but resolves itself largely into the one word: Management. As applicable to welding of piping this includes or is composed of several parts which have also been well covered previously.

1. Proper materials.
   (a) Basically as to their inherent qualities.
   (b) Artificially as to their preparation for the work involved.
2. Proper tools.
3. Proper methods and instruction.
4. Proper testing of welders.
5. Proper test to see that the failure of the human element does not destroy all of the values of the preceding factors.

It is not my intention to review the details under each of these headings because they are a matter of record, but simply to touch on those phases of the problems which have developed comparatively recently and

will endeavor to explain the reasons of research work which are responsible for or substantiate the practicability of these developments.

Preparation of Joints

First, under preparation of materials. Sketch No. 1 is the basis of most welds, either for butt welding of two pipes together or for the making of special fittings, etc. The preparation, as shown, is the same as the generally accepted standard excepting that the spacing between the bottom edges has been increased from 1/16 in. to ⅛ in. Inspection of sections cut from welds have shown a tendency for these bottom edges

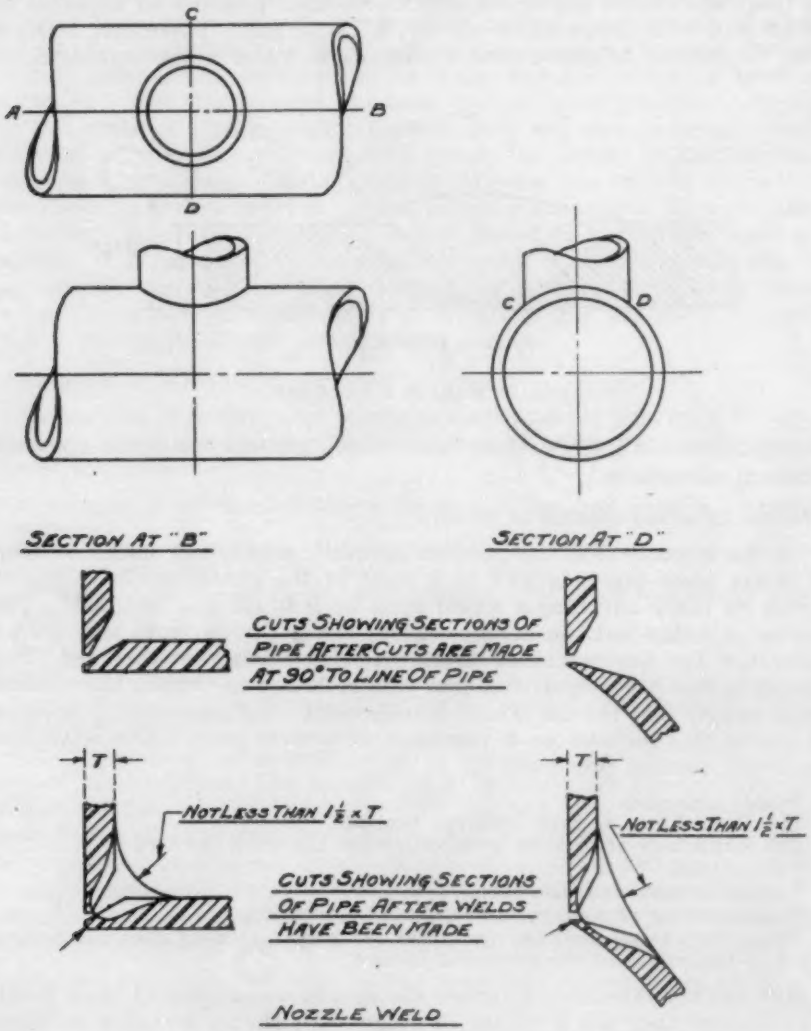


FIG. 2. PREPARATION FOR MAKING A NOZZLE WELD

to overlap after the welds had cooled and contracted. The wider spacing has shown a better condition on the inside of the pipe.

Sketch No. 2 covers the preparation for a nozzle weld. This style of preparation and welding has become a generally accepted standard.

Sketch No. 3 shows a weld at the end of the pipe when the weld is made in the shop. The end weld or plug in the end of the pipe has entirely different stresses than any other weld in view of the total pressure over

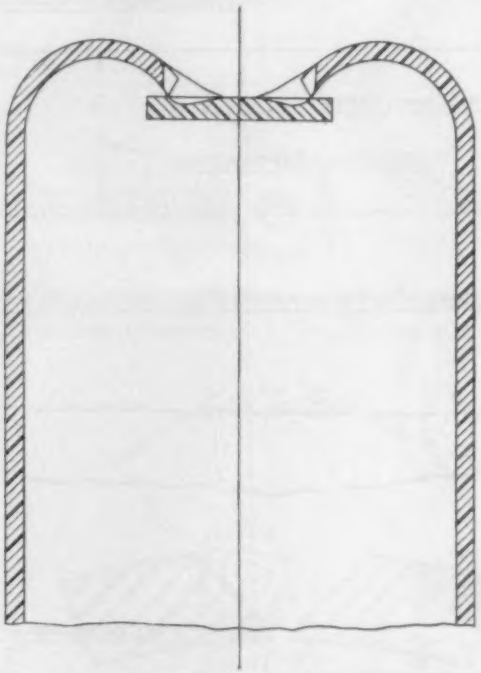


FIG. 3. MAKING PLUG IN END OF A PIPE

the area involved. This type of joint provides extreme safety in that the plate is entirely inside of a roled joint.

Following through the sketches shown covering various types of welds, attention is called to the shape of the fillets. The fillets should in all cases be so made as to provide a thickness of fillet material in excess of the pipe materials.

Sketches Nos. 4, 5, and 6 show various types of welds in common use for long lines of piping. Particular attention is called to Sketch No. 6, which illustrates two types of welds, which later in illustrating tests are mentioned as normal sockets, illustrated on the left half of the sketch and normal sockets with pins, illustrated on the right half of the sketch.

Sketches Nos. 7, 8 and 9 illustrate various types of flange welds. The use of flanges per sketch No. 7 are preferable for field welding on

account of the long skirt which prevents any warping of the flange sufficient to make it necessary to do any refacing.

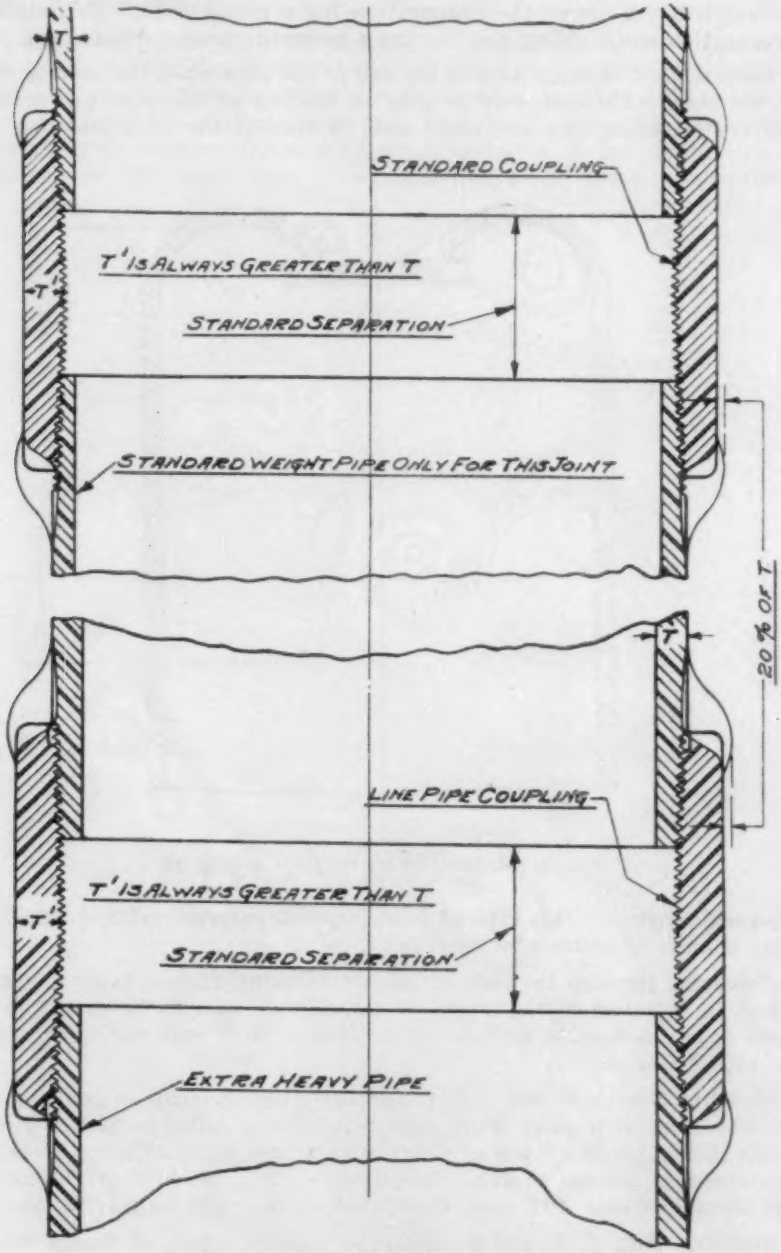
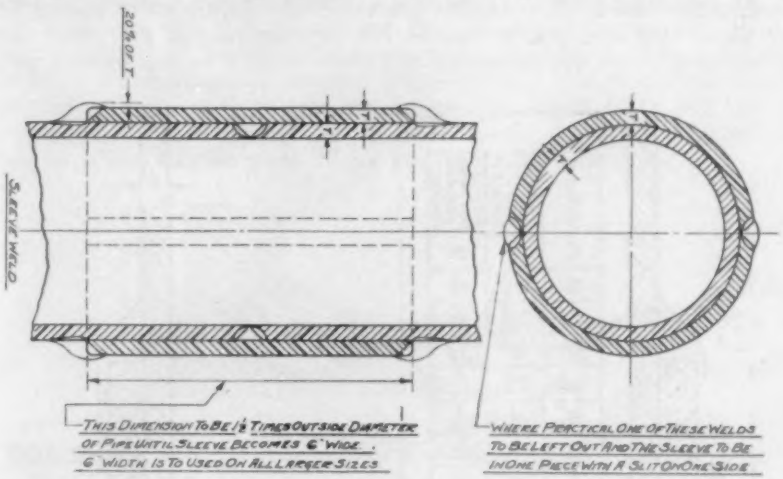


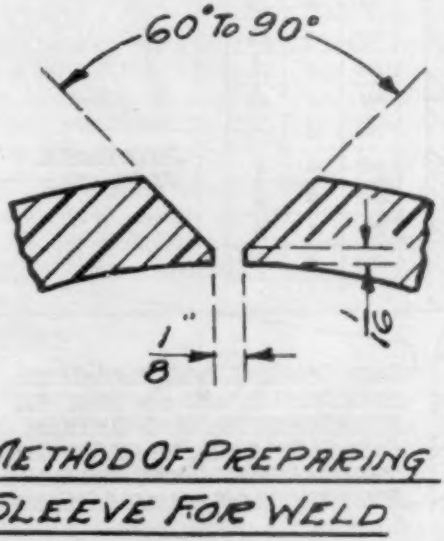
FIG. 4. COMBINATION WELDED SCREWED JOINT

The use of flanges per sketch No. 7 are preferable for field welding on

Internal Stresses

Seemingly digressing, let us consider for a moment the effect of locked in stresses due to uneven heating and cooling of the weld zone. Much


SLEEVE WELD
THIS DIMENSION TO BE 1½ TIMES OUTSIDE DIAMETER OF PIPE UNTIL SLEEVE BECOMES 6" WIDE. 6" WIDTH IS TO USED ON ALL LARGER SIZES
WHERE PRACTICAL ONE OF THESE WELDS TO BE LEFT OUT AND THE SLEEVE TO BE IN ONE PIECE WITH A SLIT ON ONE SIDE



METHOD OF PREPARING SLEEVE FOR WELD

FIG. 5. SLEEVE WELD

has been said in a general way on this point, but little has been actually proved specifically as to its effect in connection with pipe welds.

About two years ago we set about to find out what we could about the effect of these internal stresses upon the over-all strength of the pipe joint. Strain gage tests were made in connection with both annealed

and unannealed sections of 4 in. pipe and a brief summary of the results are shown by Fig. No. 10.

Fig. No. 10. These strips, ¾ x 3 in. long, were cut from the pipe at points indicated. The results are relatively unimportant except that they show that the entire strains are in compression and they show further that there are relatively different strains in unannealed pipes.

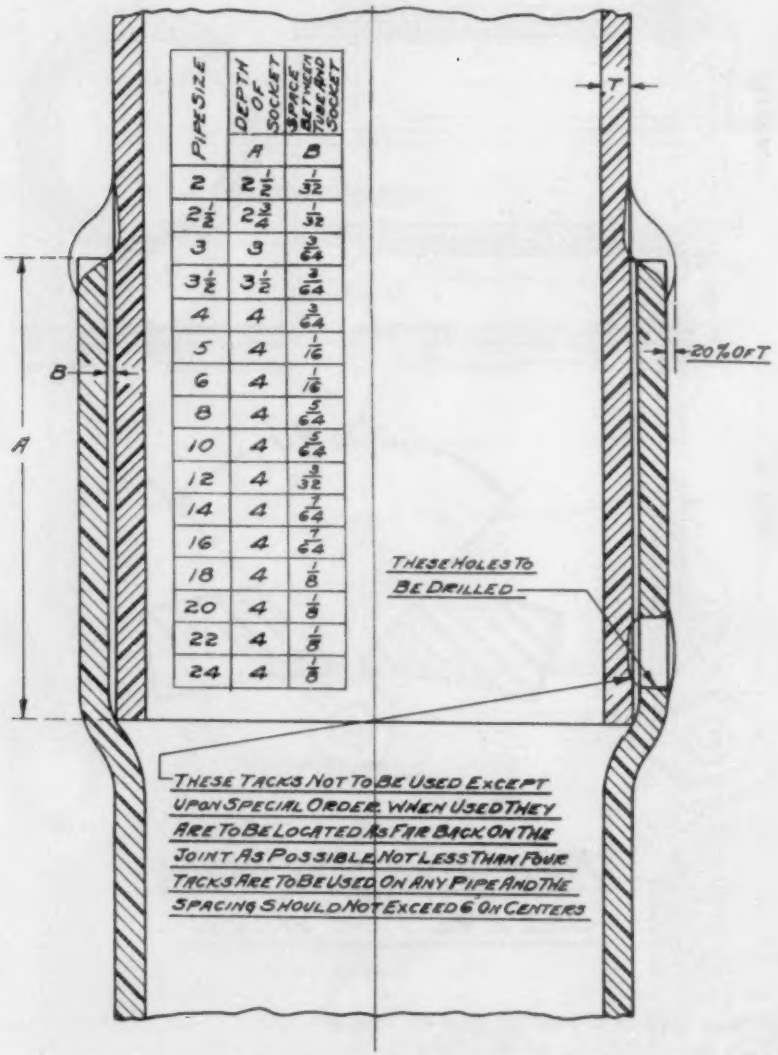

PIPE SIZE
DEPTH OF SOCKET
SPACE BETWEEN PIPE AND SOCKET
A
B
2 2½ 1/32
2½ 2¾ 1/32
3 3 3/64
3½ 3½ 3/64
4 4 3/64
5 4 1/16
6 4 1/16
8 4 5/64
10 4 5/64
12 4 3/32
14 4 7/64
16 4 7/64
18 4 1/8
20 4 1/8
22 4 1/8
24 4 1/8
T
20% OF T
THESE HOLES TO BE DRILLED
THESE TACKS NOT TO BE USED EXCEPT UPON SPECIAL ORDER. WHEN USED THEY ARE TO BE LOCATED AS FAR BACK ON THE JOINT AS POSSIBLE. NOT LESS THAN FOUR TACKS ARE TO BE USED ON ANY PIPE AND THE SPACING SHOULD NOT EXCEED 6" ON CENTERS
NORMAL SOCKET FOR WELDING

FIG. 6

This method of testing was not carried forward to reach any definite conclusions.

We knew that we could cut coupons from welded pipe and with welds made by trained welders which, when pulled, would break outside the weld zone, but this did not answer that continually recurring question about the effect of internal stresses because when the coupon is cut from the joint the mechanical stresses are released. We, therefore, decided that the most practical test to determine this would be to pull the pipe with the welds in its entirety or, in other words, pull full section samples. This work was started more than a year ago with 4 in. pipes.

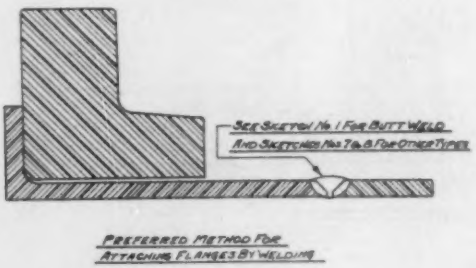


FIG. 7

Tests of Welded Pipe

In making some of the early tests on 4 in. samples, the pulling machine used required flanges for bolting. These flanges were welded to the end of the pipe. It was impossible to develop flanges even screwed through and back welded, which would develop as great strength as the intermediate butt weld or the pipe itself.

The lap joint was drawn right through the flange. It was not until we made heavy laps, now known as the Grinnell Triple-Ex XXX Line, that we could develop sufficient strength in a flanged joint to break either the pipe or the weld intermediate.

The foregoing illustrations are interesting only by way of showing what led up to the later tests.

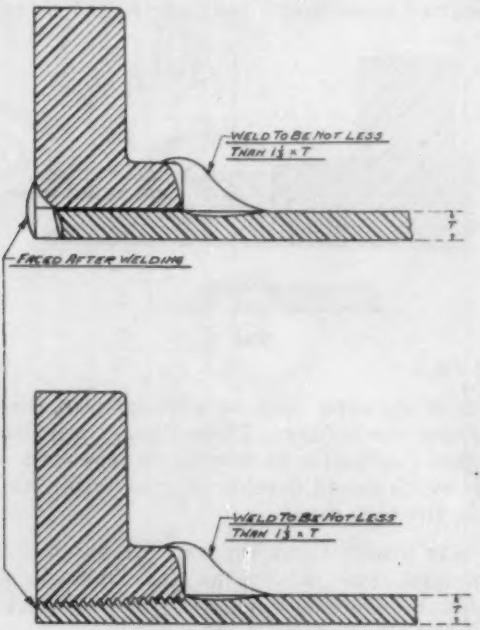
We decided after a number of tests of both annealed and unannealed sections that the 4 in. pipe did not represent the worst condition as regards the internal stresses and therefore shifted our work to another laboratory capable of pulling larger pipes. The work thus started created considerable interest and was carried on by other parties on a much larger scale and I am privileged through the courtesy of the National Tube Co. to show you an advance report of the results of a long series of tests along this line.

Fig. 11 shows a summary of three types of welds which were tested. It will be noted that even those pieces which broke in the welds themselves held an average tensile load practically equal and, in many cases, in excess of the pieces which broke entirely outside of the weld zone. It might be added that no pieces in the entire test broke at a point which indicated low strength.

FIG. 6

Fig. 12 indicates two pieces of 8 in. pipe made up with Normal Socket welds, as shown by Sketch No. 6 and which broke entirely outside of the weld.

Fig. 13 indicates two pieces of 12 in. pipe made up with socket welds with pins, also as illustrated by Sketch No. 6. By carefully noting the picture it will be found that cracks developed around the pins due to the extra strains set up in the joint by same. These cracks developed long before the pipe itself or the joint could be broken.



FIGS. 8 AND 9. FLANGE WELDS

Fig. 14 shows two pieces of 16 in. pipe made with a regular butt weld, as shown by Sketch No. 1. One of these, it will be noted, broke entirely outside of the weld zone and the other one directly in the weld. Piece marked No. 6517, however, broke at 446 tons pull, and piece No. 6520 broke at 448 tons.

Fig. 15 shows a screw coupling back welded in 14 in. pipe, as shown by Sketch No. 4. This shows one of the earlier tests not included in the above series and is included in the illustration merely to bear out the fact that this type of weld is a strong and safe weld.

Beyond what details were learned from these tests they show that when properly designed for reinforcement and when made by properly trained welders, these joints in varying types can be made to overcome whatever internal stresses are locked in, as none of these joints were annealed.

indicated low strength.

Going back again to the matter of design and shapes of fillets. The importance of building up the welds, as already mentioned, was one of the things learned in the preliminaries to this remarkable set of tests.

Another thing developed in these preliminaries was the shape of the welded fillet. To approach perfection, the lines of force should be kept as nearly straight as possible. This means making the shape of the fillets gradually sloping without abrupt turns, otherwise under stress the sharp corner checks, gradually throwing the stresses further inward toward the pipe material itself. This accounts for the shape of the fillets, as shown.

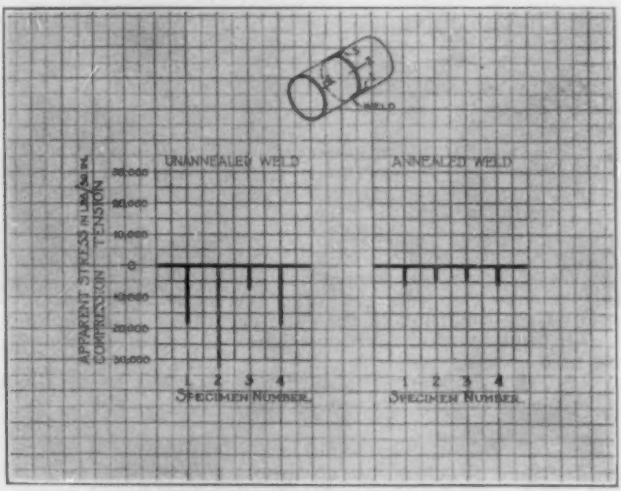


FIG. 10. STRAIN GAGE TESTS OF ANNEALED AND UNANNEALED PIPE

By referring back to the sketches covering the preparation of various types of welds, it will be seen what is meant by the building up of fillets and the design of what might be called stream line effects in same.

The writer has had no cause to change his original ideas as to the efficiency of the plain butt weld as compared to mechanically reinforced types, and it be interesting to note that the results show somewhat greater strength for this type of weld over others in the series of tests illustrated. It is the writer's belief that adding straps or reinforcements complicates the stresses which are as proved by these tests now well harnessed or overcome by careful design and workmanship. The only portion of this series of tests which in any way indicate this, however, are the relative tests of Normal Socket Welds as compared with Socket Welds with Pins, the latter usually fracturing around the pins before either the joint itself or the pipe was fractured. In other words, the addition of the pins apparently added nothing to the over-all strength of the joints and detracted something in that a leak was caused to appear around the pins under comparatively lower tensile pull.

Management

Instruction of Welders has been many times emphasized and full data on this subject is available. The testing of welders is of extreme importance, and in addition to having coupons pulled at regular intervals, we have found another test very valuable both to impress the welder with what his work must be made to accomplish and as a practical check upon the general quality of welding. This test is the final practical one used for checking either oxyacetylene welders or electric-arc welders.

Fig. 16 illustrates a piece of pipe tested in accordance with our standard instructions, which are as follows:

"Each welder before being considered qualified to operate must pass the following prescribed test.

1. Prepare two pieces of 6-in. standard weight pipe, each end beveled as per our standard and with extra heavy lap joint flanges on the opposite end of each piece to which must be bolted extra heavy blind flanges with a test connection.
2. The welder must then make a complete butt weld according to our standard specifications. This completed piece must be tested to 750 lb. hydraulic pressure and thoroughly hammered around the circumference of the weld while the pressure is applied.
3. The sample must then be placed on our bending table with a bending shoe located approximately 6 in. back of the center of the weld and then pulled cold until the pipe collapses practically flat.
4. After this is done the weld and pipe are to be examined for any visible cracks and, if the condition of the pipe permits, it is to be again placed on the test rack and hydraulic pressure applied to be certain that there are no cracks in the weld.

A welder who has successfully passed this test will be considered qualified for independent work on our welded piping."

RESULTS OF TESTS ON WELDED JOINTS MADE ON ONE SIZE OF PIPE BUT WITH DIFFERENT TYPES OF JOINTS

Pieces Tested	Types of Joints	Broke Off in Welds Pcs.	Broke Off in Welds Loads in Tons	Broke Off in Pipe Pcs.	Broke Off in Pipe Loads in Tons
	Pipe 4" O. D. × .1875" thick				
6	Normal sockets	—	—	6	67,000
6	Socket and pins	—	—	6	67,833
6	Butted joints	—	—	6	69,000
	Pipe 8" O. D. × .1860" thick				
6	Normal sockets	—	—	6	140,160
6	Socket and pins	—	—	6	140,160
6	Butted joints	1	147,000	5	131,800
	Pipe 12" O. D. × .2500" thick				
6	Normal sockets	1	288.00	5	270,400
6	Socket and pins	1	262.00	5	252,000
6	Butted joints	1	280.00	5	283,400
	Pipe 16" O. D. × .3125" thick				
6	Normal sockets	4	426.50	2	420,000
6	Socket and pins	6	377.83	—	—
6	Butted joints	5	431.20	1	446,000
—		—		—	
72		19		53	

FIG. 11

In Fig. 16 point "A" represents the weld in the piece and "B" represents the point at which the bending shoe was located. In this photograph the piece has passed through its second testing and has started to crack at point "B" under approximately 500 lb. pressure.

Finally, the rigid enforcement of a test of the finished product insures not only the purchaser of receiving materials suitable for the purpose intended, but also is insurance for the fabricator that "management" is functioning and the operators are performing to the requirements. Our required test for high pressure steam piping when welded is as follows:

FIG. 12. NORMAL SOCKET WELDS

FIG. 13. SOCKET WELDS WITH PINS

FIG. 14. BUTT WELDS

"Welded piping material will be subjected to a hydrostatic pressure of three times the maximum allowable working pressure. Welds shall be hammered while under test, the hammering to be done all around the weld on both sides with a hammer weighing from 2 to 6 lb., depending on the size of the pipe, and the blows shall be as heavy as possible without deforming or injuring the material."

A question is often raised as to the behavior of welds under high pressures and temperatures. With increased steam pressures, the piping materials are correspondingly increased in weights. The proper design of welds necessarily provides for a proportionate increase in the thickness of fillet and building up of the welds so that the relative strength of the joint is maintained. Recently there was a most interesting article written into your records as a preliminary report on the subject of "Welds at Elevated Temperatures," in which one of the conclusions reached after some very excellent research work was: "As far as ultimate strength is concerned, a strong weld cold is in general a strong weld hot." This conclusion would indicate that welded joints made to proper design are just as safe proportionately when used in connection with the high pressures and temperatures encountered in the modern public utility power plants as they have been found to be by years of trial and experience operating under the lower pressures.

It seems highly probable that as usual actual practice will demonstrate, as it is now aready doing in higher pressures and temperatures, the practicability of carrying on with progress in this field while we follow

with research work, substantiating the correctness of those practices. There remains yet to be done in this field of research the collection of data relating to the strength of welds under torsional strains. In actual practice it has been proved through years of actual service in pipe bends and at strategic positions in pipe lines where expansion and con-

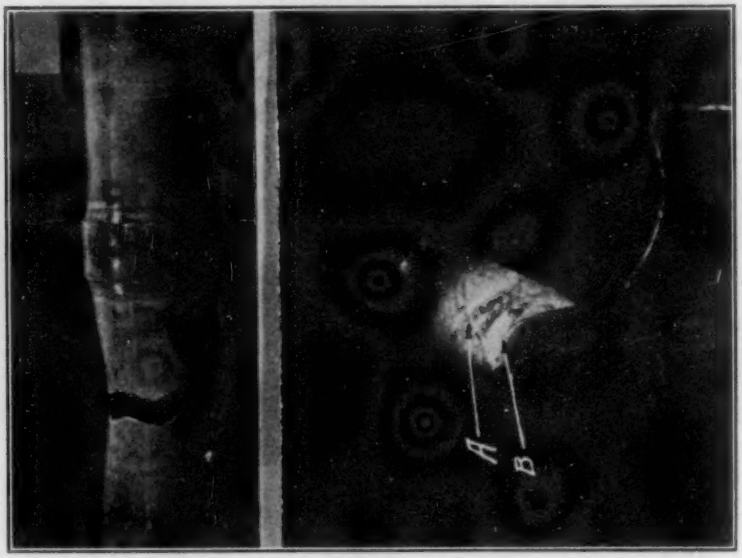


FIG. 15. SCREW COUPLING

FIG. 16. MAKING STANDARD TESTS ON WELDED PIPE

traction strains and vibration are most vicious that properly made welds are altogether safe.

Engineers responsible for the piping going into these so-called superpower plants realize that they are dealing with a problem where a single failure may be of tremendous import. Therefore, they can only be commended if at times they seem extremely rigid in their specifications and over careful as to the ability and integrity of the pipe fabricator.

Arc Welding as a Manufacturing Tool*

By J. F. LINCOLN†

ARC welding has been of great benefit to mankind in numerous ways. It was first thought of as a plaything, then as a repair tool, then as an eliminator of rivets, and now as a manufacturing tool for the elimination of castings and forgings.

The advantage of welded structural steel over casting is because of the following facts—steel has a tensile strength of approximately 50,000

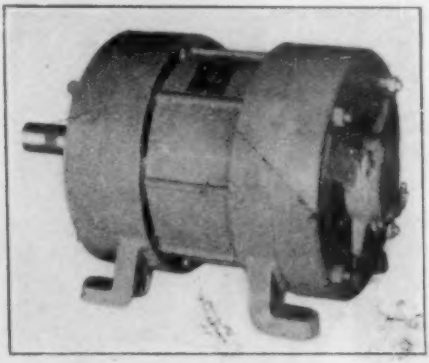


FIG. 1. THIS IS A BALL BEARING MOTOR MADE ENTIRELY OF WELDED STEEL CONSTRUCTION. THE END RINGS AND END BRACKETS BEING MADE FROM ANGLES AND STANDARD SHAPES

lb.—cast iron 10,000 lb.; steel has a modulus of elasticity of 30,000,000—cast iron 12,000,000; structural steel has a cost of less than 2c. per pound —cast iron, in the form of castings, a cost averaging about 6c. per pound.

Therefore if a structure is to be made in which its success depends on tensile strength, it is self evident that only one-fifth as much steel is required and at one-third as much per pound, or the total cost of the material being one-fifteenth as great as with cast iron. If the success of the structure depends on its stiffness as in a base, steel being two and one-half times as stiff and costing one-third as much per pound, that the ratio between the cost of the two would be one to seven and one-half.

Steel also has an added advantage in that it requires a smaller factor of safety for the same degree of safety as cast iron.

Another advantage that this construction gives is the fact that it makes possible for large manufacturers of iron and steel products to increase the range of their operations with but very little increase in their investment. By this process the overhead, sales expense and profit of the

*Presented before the Cleveland Section, American Welding Society, Oct. 27, 1927.

†Vice-President and General Manager, the Lincoln Electric Company, Cleveland, Ohio.

foundry is eliminated from the manufacturer's cost by the putting in of arc welding equipment of comparatively low first cost.

Objections Easily Overcome

The following objections are urged against this welded steel construction by those not fully familiar with its possibilities.

1. Appearance.
2. It is urged that it is not possible to know when a weld is properly made by visual inspection.
3. In the attempts that have been made by people not fully versed in the art, they do not show savings.
4. The entire upset of the previous manufacturing methods.
5. The requirement of many new tools.

FIG. 2. THIS SHOWS THE DIPPER OF A STEAM SHOVEL FABRICATED ENTIRELY OUT OF WELDED STEEL

It is evident that the appearance of many structures when made from steel will be changed from their appearance when made from cast iron. The very massive construction necessary with cast iron will be changed to the very much lighter and sharper contour of standard steel shapes. Whether this is an advantage or disadvantage depends on the point of view. Any change from what we are used to is objected to by many people, but I think it is safe to say that in the minds of the average engineer the structure which does the work to best advantage also has the best appearance.

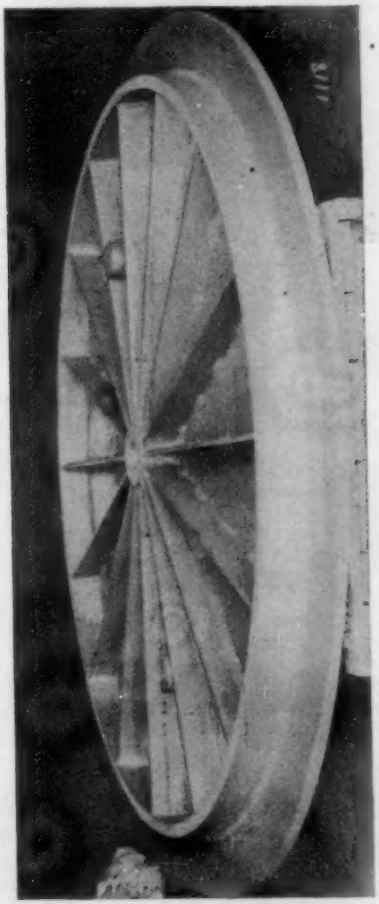


FIG. 3.

COMPLETE TURNTABLE		
CAST IRON	8,435 lb.	$506.00
COST		
WELDED STEEL	2,412 lb.	$151.00
COST		
SAVING	6,023 lb.	$355.00

As regards the efficiency of a weld, any one who has had any experience with welding can tell whether proper penetration has been accomplished by the shape and appearance of the bead.

Many cases of redesign have been attempted by those who have not been experienced in this line, in which the desire is to copy the appearance of the cast structure and by so doing the advantages of economy

have been largely overlooked. If the engineer will start out with the well known strength and stiffness of steel shapes and design for the requirements of the situation with the proper shapes and with the proper design for the use of welding, great economies in almost all cases can be effected. This opens up large possibilities for the engineer.

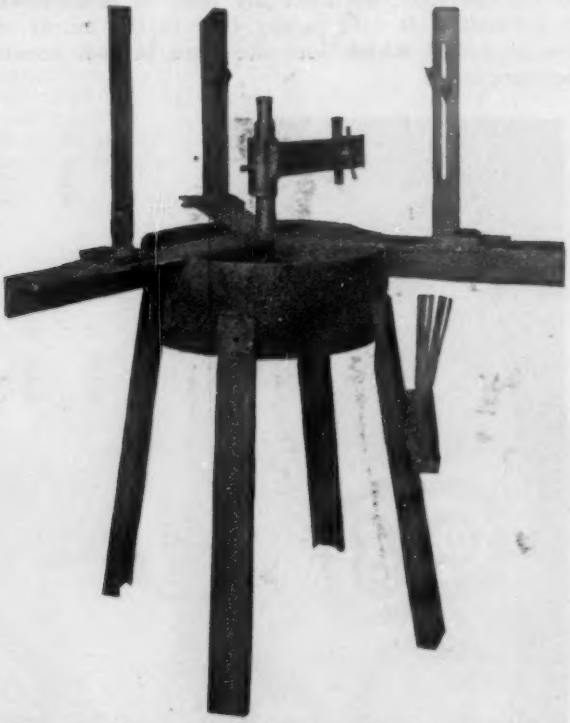


FIG. 4. USE OF WELDING IN A MANUFACTURING PLANT IN THE CONSTRUCTION OF SPECIAL TOOLS, JIGS AND FIXTURES, WHEREIN IN THE MOST CASES ONLY ONE WAS MADE AND THE COST OF CASTINGS WHERE THE PATTERN CHARGE MUST BE ABSORBED AGAINST THE ONE MACHINE IS VERY HIGH

Change to Welded Parts Easily Made

The application of welding to the redesign of parts if done in the proper way will not upset factory organization or methods at all. The change-over should be made by degrees and in a way which will be gradual. In this way the shop methods instead of being upset will be greatly assisted by the accumulated experience of those who have intelligently followed this new departure.

Very few new tools are required for the application of arc welding. In general all that is necessary is the welder itself and the addition of perhaps bending equipment of a simple nature since most shapes can be bought from the warehouse stocks or direct from the mill, which are applied directly into the work itself.

It is safe to say that in excess of 75 per cent of all cast structures now made can be replaced by structural steel welded with economy.

There are two other advantages which have not been stated heretofore which are of very great importance. The first is that by the use of this method patterns will be largely eliminated and their first cost, cost of

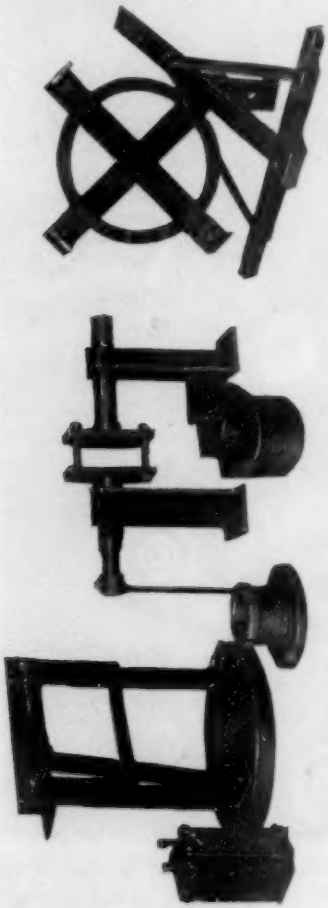


FIG. 5. A VARIETY OF JIGS AND FIXTURES MADE BY THE USE OF WELDED STEEL CONSTRUCTION

upkeep, and cost of storage will be one of the large savings effected by this method.

Few shapes are needed in order to manufacture a large variety of forms and therefore the total amount of inventory carried will be but a fraction of that were castings used rather than the structurals. In general also the storing of these shapes will take very much less room, and very much less handling facilities.

There is also the advantage in the case of many structures that the element of time can be very considerably reduced by this new method

so that a design can be completed and manufactured in less time than the patterns themselves can be made in the case of the previous method. Instead of the routine being the designing, drawing, pattern making,

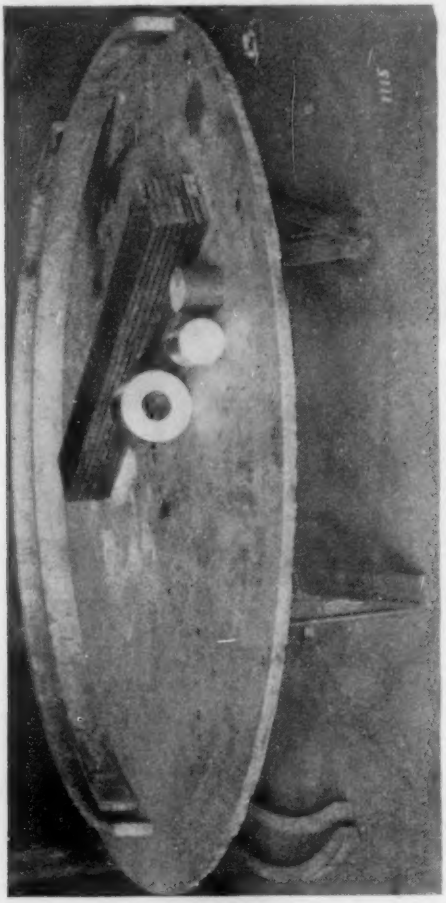


FIG. 6. THIS SHOWS THE FEW SIMPLE PARTS NECESSARY TO WELD INTO THE TURN-TABLE SHOWN IN FIG. 3.

casting, machining, the new routine will be the designing from sketches and the manufacturing, thus making a great saving in time because of the elimination of the completed drawing, manufacture of the pattern, and the making of the casting.

A few examples of parts which have been successfully manufactured in this way are given in the illustrations. In these cases no account is taken of overhead which is of course a very real part of the total cost. The cost of overhead will be very materially reduced because many of the costs going into overhead with the usual cast construction are eliminated by the steel construction. Therefore, a fairer comparison is of material and labor in both cases rather than the inclusion of overhead although an item of overhead would of course be present in both cases.

Spot Welding of Aluminum and Its Alloys*

By W. M. DUNLAP†

Introduction

THE increased use of aluminum in assembled articles has pointed out strongly the need of developing the commercial spot welding of this metal. It has been known for some time that aluminum and its alloys could be spot welded.

The question of spot welding aluminum has been quite extensively studied in the laboratories of the Aluminum Company of America. Early in this study it was necessary to determine what was to be considered a good weld, so as to establish a standard of comparison. It was found true, and our experience has been corroborated by the work of others on other metals, that the best spot weld is one which pulls out of the welded sheet so as to leave a hole, as shown in Figure 4. It was found that such welds could be made in 28‡ and in the alloys 3S, 17S, 25S and 51S, and that this method of determining quality is reliable as a rough test.

The results obtained, all of which have been put to practical use, have been reviewed and collected in the following pages. This paper embraces the major results of the study and includes some specific recommendations in regard to the proper practice to be followed in the spot welding of aluminum.

Apparatus

A Spot Welder having a rated capacity of 20 kw. was used in this investigation.

The machine has a five point switch (marked A) for controlling the current in the secondary circuit. It also has a spring and adjusting nut (marked B) for controlling the mechanical pressure applied to the work between the electrodes during the process of welding. The time of current application is regulated by the speed with which the foot treadle is depressed.

Development of Electrodes

Early in this work it became apparent that if the spot welding of aluminum was to become a commercial success, an electrode that would not alloy very readily with aluminum must be used. Several types of electrodes were tried out, including several of the patented electrodes that are now on the market. Neither plain copper electrodes nor the patented ones proved wholly satisfactory for welding aluminum. Copper and aluminum alloy with extreme readiness and copper electrode points are very soon coated with a layer of copper-aluminum alloy. When the electrode points become thus coated, the quality of the welds is very poor and there is great danger of burning a hole in the sheet due to

*Presented before Detroit Section, American Welding Society, Jan. 6, 1928.

†Metallurgist, Technical Direction Bureau, Aluminum Company of America, New Kensington, Pa.

‡28 is Aluminum Company of America's designation for commercially pure aluminum; 3S is aluminum-manganese alloy; 17S is duralumin; 25S is aluminum-copper-manganese-silicon alloy; 51S is aluminum-magnesium-silicon alloy.

arcing. It is thus necessary to clean copper electrode points with a file or with emery cloth quite frequently. This, of course, means that the operator must spend a considerable part of his time cleaning electrodes.

In considering the requirements for a good electrode, there was every reason to believe that chromium would be an ideal metal for this purpose. As an electrical conductor, chromium is a little better than aluminum. The melting point of chromium is about 2800 deg. Fahr., which is nearly 1600 deg. Fahr. higher than the melting point of aluminum. Chromium does not alloy with aluminum very readily, and this puts it far ahead of copper as an electrode material for welding aluminum. Furthermore, chromium is hard enough not to lose its shape

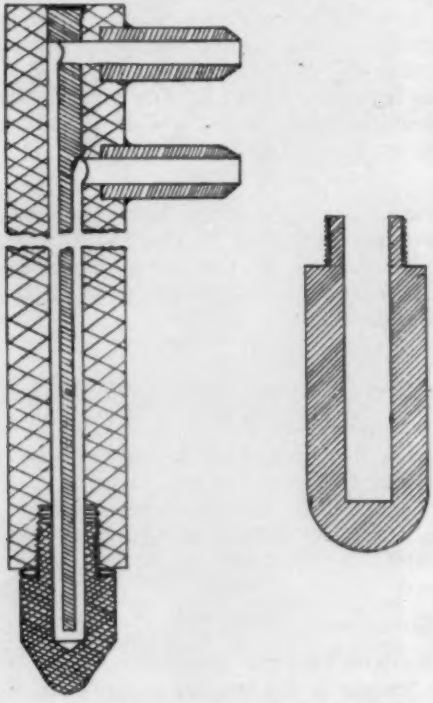


FIG. 1. WATER COOLED ELECTRODE AND WELDING TIP (LEFT). HEMISPHERICAL TIP (RIGHT)

due to the pressure exerted during the process of welding. The only pure chromium obtainable at this time was in the form of chromium rods ¼ in. in diameter. An attempt was made to tip some of the copper electrodes with this rod, but it was too brittle to work with, and chromium plating the copper electrode was resorted to. A number of copper electrodes were chromium plated and the machine put in production on an article requiring 15 spots for its assembly. With the introduction of chromium plated tips the daily production rose to 10,500 spots as com-

pared with 5250 spots for copper electrodes on the same article. When welding 2S or 3S metal 1500 to 2000 spots can be made with one pair of chromium plated electrodes before they will require dressing and replating.

The electrodes are made from copper rod one inch in diameter, the welding tip being rounded on a ¼ inch spherical radius (Figure 1). The purpose of using this rounded welding tip is to produce a spot uniform in shape and quality. The rounded tips produce a dished spot in the sheet, but if the current density and pressure are correct the

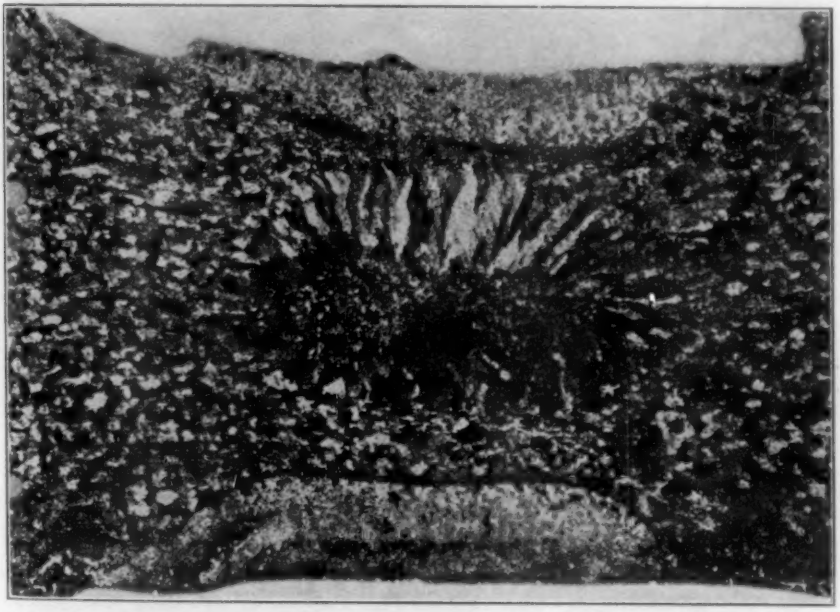


FIG. 2. MICROGRAPH OF A LONGITUDINAL SECTION OF A SPOT WELD IN 2SO SHEET, SHOWING CRYSTAL STRUCTURE OF METAL UNAFFECTED BY WELDING, DEPRESSIONS ON SURFACE OF SHEET CAUSED BY ELECTRODES, AND CHANGE IN CRYSTAL STRUCTURE AT WELD INDICATING THAT METAL HAS BEEN MELTED AND HAS RUN TOGETHER FORMING A CONTINUOUS UNION BETWEEN THE TWO SHEETS. 2SO METAL, 50 DIAMETERS MAGNIFICATION

depression is not deep enough to be objectionable. It has been claimed that electrodes with hemispherical tips, as shown in Figure A, will automatically reduce the current density as the electrode sinks into the metal and thus prevent excessive melting. This expedient seems of dubious merit and carries the disadvantage of producing a deeper indentation than desirable. However, it has been found that welding of very thin gauge sheet (from 0.010 in. to 0.020 in. thick), which is very difficult with flat tipped electrodes, can be readily performed with rounded tips. When flat pointed conical tips are used, it is very difficult to prevent eccentric contact between the tips and the sheet, which causes a concentration of the current at one point and results in an uneven spot.

A very satisfactory method of determining whether the electrodes are in perfect alignment is to place a piece of polished metal between the tips, apply the foot pressure, and rotate the sheet through about one-fourth of a turn. If this leaves a mark showing concentric circles with a center at the middle of the tip, the electrodes are properly adjusted; but if the mark is off center and irregular the relative positions of the electrodes must be altered or their tips ground by rotating a file between them with the foot pressure on until the adjustment is correct. Of course, chromium plated tips must not be ground or filed. The

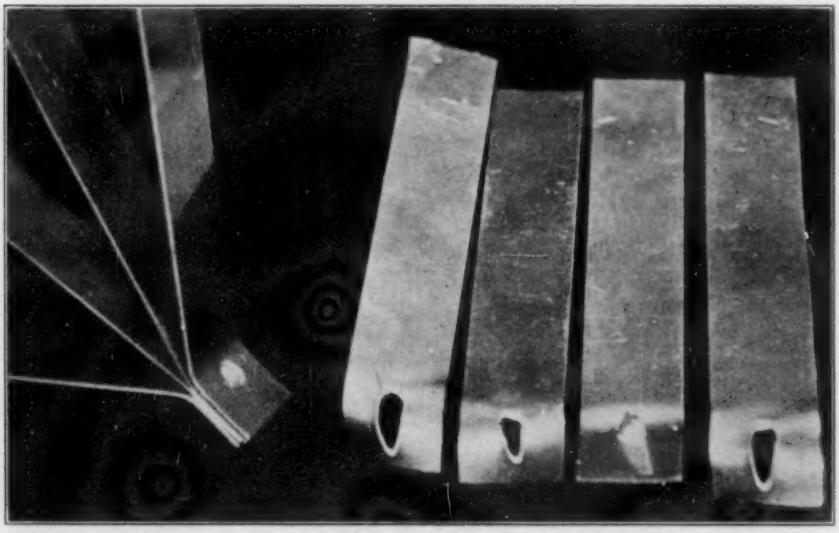


FIG. 3. SPOT WELD IN 0.032" 2SO SHEET SHOWING HOW FOUR SHEETS MAY BE WELDED TOGETHER IN ONE OPERATION, AND THE NATURE OF THE FAILURE WHEN THE WELD IS TORN APART

electrodes are drilled to within ½ inch of the contact surface and water is circulated through them to keep them cool.

Method of adjusting Machine

The method used in determining the proper setting for the control switch and pressure spring nut to spot weld any particular gauge and grade of sheet is as follows:

With the switch set on point No. 1, which gives the lowest current density, and the pressure spring nut set in the position which exerts the minimum pressure, two pieces of sheet are laid one on the other and placed between the electrode points. The treadle is depressed until the electrode points just touch the sheet, then pushed down steadily to the end of the stroke. One of three things happens.

First, let us assume that the two sheets are simply stuck together with a small bead of metal, and break apart very easily. This indicates that not sufficient current or time, or too much pressure, has been employed

in making the weld. A longer time of current "dwell" is first tried. If this is not productive of satisfactory results, the control switch is next moved up to point 2 and the operation repeated, with subsequent advances to points 3, 4, or 5, if required. Since the pressure is adjusted to the minimum, this adjustment is not altered. If no satisfactory weld is obtained on point 5, it is indicated that the machine has not sufficient capacity to weld that particular thickness and grade of sheet.

The second possibility is that a real weld forms. This indicates that the machine adjustment is approximately correct for the particular material under consideration. If, however, the weld is not entirely satisfactory, in that the area of the weld is smaller than the contact area of the electrode points, some manipulation of the switch and spring setting will bring this about. If the weld is small, it is indicated that not enough heat has been generated in welding. To remedy this condition, more current is supplied by moving the switch up a point, or more resistance is introduced in the sheets by decreasing the pressure between them. If the spring is set to exert minimum pressure it cannot be used to introduce more resistance. It is therefore necessary to increase the current by changing the switch adjustment. It is generally safer, in such a case, to increase the pressure slightly with increase of current, and then to subsequently decrease it in case the higher pressure is not necessary. It is possible that the increase in current between any two points is greater than desired, and the above precaution of slighty increasing the pressure is exercised to counteract the excess. Once the proper switch adjustment has been found, final adjustments of pressure and time will result in the production of satisfactory welds.

The third possibility is that the current passing through the electrode points is too heavy for the sheet to carry, and arcing takes place. The arcing generally burns a hole through the sheet and also pits or coats the electrode points. If, as supposed, the switch is set on point 1, it is impossible to decrease the current. By increasing the pressure sufficiently, thus reducing the resistance to the current through the sheets, arcing can finally be prevented, and further small adjustments of pressure and time will result in the production of satisfactory welds.

Occasionally it has been found that with minimum spring pressure, one switch setting causes arcing, while the next lower switch setting produces a poor or weak weld. In this case it is necessary to employ that switch setting which has caused arcing, and to increase the spring pressure. This procedure will be effective in eliminating the arcing and producing a satisfactory weld.

From the above discussion it is obvious that each of the three factors, time, current, and pressure, has an important effect upon the quality of the weld, and that judicious adjustment will allow of making a satisfactory spot weld under circumstances which ordinarily seem most unfavorable. In working out the conditions for spot welding a particular thickness of metal, the best general rule to follow, we believe, is to employ as high a current and as low a pressure as is possible without danger of arcing.

It was deemed advisable to determine, if possible, the fixed values of

current, pressure and time for spot welding various gauges of sheet of the various aluminum alloys. However, by varying the time and pressure, it was found that the limiting values for the current covered a wide range. Therefore no very definite values for these quantities could be suggested as proper ones for welding some particular gauge of aluminum sheet. The values of the current across the electrodes and the mechanical pressure recorded are only approximate, and are merely intended to give some idea of the requirements for a particular gage of sheet.

Metal	Thickness of Sheet, In.	Amps in Secondary	Pressure in Lb.
2S	0.20	4,700	80
	0.030	5,900	80
	0.040	6,800	90
	0.050	7,600	90
	0.060	8,500	95
3S	0.020	4,800	80
	0.040	6,000	85
	0.060	6,800	95
	0.080	7,500	95
	0.100	8,100	100

SPOT WELDS IN ALUMINUM

Preparation of Sheet:

Aluminum is easily welded and requires no special preparation. The main requirement for a satisfactory weld is that the metal must be clean and free from dirt or heavy oxide coating, which would prevent metal-to-metal contact. All aluminum and aluminum alloy sheet is covered by an oxide film. With 2S and 3S metal the film is only of very slight extent and it has very little influence on the welding conditions, but the fairly heavy oxide film on the heat treated alloys 17S, 25S and 51S calls for special treatment. The oxide is of very high resistance, and when high enough voltage is used to break down the film, there usually results such a rush of current when the oxide film breaks down that the metal being welded quickly overheats, causing it to melt and form blow holes through the material before the current can be shut off. When the oxide film does not cause blowing, the welds have oxide inclusions which make a weak, brittle weld. It has been found that the presence of thin films of oil or paint, either wet or dry, between the aluminum sheets have practically the same effect upon the spot welding conditions as does the oxide film. It is possible to spot weld aluminum through such films, but heavy mechanical pressure will be required in order to obtain good contact between the surfaces.

In general, better results are obtained when the surface of the sheet to be spot welded is clean. Dirty metal may be cleaned by abrasion or dipping in caustic, followed by a nitric acid dip to neutralize the caustic adhering to the surface of the metal.

Mechanical Properties:

Since spot welding is similar to riveting, efficiencies for the one may be expressed in the same terms as have been used for the other. For rivets, the practice is to express the efficiency as the ratio of the strength

of one inch of width of the joint, to the strength of one inch of width of the continuous metal.

Some considerable variations in the value for the strength of spot welded joints were encountered when tensile tests were made on them. Due to lack of equipment suitable for testing larger pieces, only specimens one inch in width were tested, and all values are given in terms of this type of specimen. 0.050 inch 2SO[1] flat sheet was arbitrarily selected for use in this work of determining the efficiencies of spot welded joints. Joints were prepared by fastening together two strips end to end, using

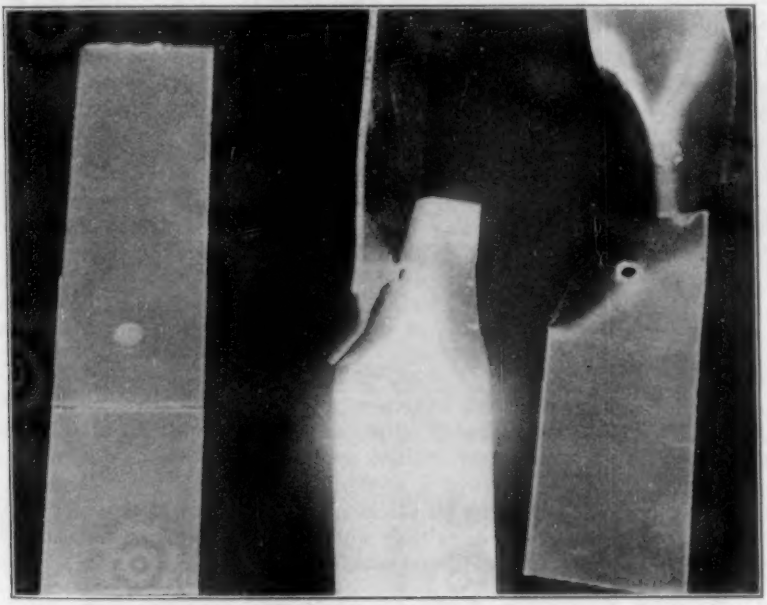


FIG. 4. SPOT WELD IN 0.064" 2SO SHEET SHOWING APPEARANCE OF SPOT WELD AS FORMED, WELD PARTIALLY BROKEN SHOWING IT TEARING OUT OF SHEET, AND WELD COMPLETELY BROKEN

one, two, three and four spots. This caused some crowding of the spots when the large numbers were put on the sheets, which may have been responsible in some way for the erratic results obtained, that is, the distance between the spots may have had an effect on their respective strengths.

In the case of single spot joints, to give a typical example, some strips of one inch wide, 0.050 inch thick 2SO flat sheet were welded with one spot, tested, and found to have an average strength of from 250 to 260 pounds. If this strength is referred to the strength of a strip of the original metal one inch wide, to express a per cent efficiency, about 38 per cent is obtained for the efficiency of a single spot. The tensile strength of the metal used—2SO flat sheet—was 13,700 pounds per square

[1] O indicates annealed material.

inch. Relatively little variation was found in the strength of different joints of this type, the lowest being 35 per cent and the highest 40 per cent.

In the case of two-spot joints, a range between 396 and 454 pounds was found for the strength of the sheet. The average value was 420 pounds and the average efficiency 63 per cent.

In the case of three-spot joints, the following results were obtained—a minimum of 506 pounds, a maximum of 598 pounds, an average of 561 pounds, and an average efficiency of 84 per cent. The spots were placed at the vertices of a triangle with one side parallel to the end of the strip.

As explained before, a strip one inch wide was the maximum width which could be tested. Consequently, when a joint formed with four spots was tested, no value could be obtained for its strength because the sheet failed. In other words, the joint was as strong or stronger than the original sheet.

These results were found to be fairly typical of what could be expected of the welds. In places where the question of fastening the sheet is the important point, and no great forces must be resisted by the joint, a relatively small number of spots would be sufficient. In other cases, under other requirements, the number could be increased, the limit being four per inch of the joint, beyond which no further advantage in strength would be desirable. Of course, this refers only to spots in 2SO sheet.

Metallographic Structure:

A micrograph of an etched section of a spot weld in 2SO sheet is shown in Figure 2. The area, roughly elliptical in shape and bounded by radial crystals, has been completely melted so that metal from the two sheets has run together and formed a continuous union between them. The structure of the metal in the elliptical area is typical of that of a chilled casting. The light areas on either side of the photograph result from contact with the electrodes during welding.

Spot Welding Aluminum Alloys of Dissimilar Composition:

The possibility of spot welding together two alloys of a different composition was investigated. It was found that aluminum of an aluminum alloy of one composition, say 2S or 3S, could be spot welded to an alloy of a different composition such as 17S, 25S or 51S.

Maximum Thickness of Metal That Can Be Welded:

The maximum thickness of the various alloys that could be satisfactorily welded on the machine used was determined. The maximum thickness for 2S and 3S was found to be 0.064 inch and 0.120 inch, respectively. The maximum thickness for 17S, 25S and 51S was found to be 0.064 inch. The values mentioned are for two pieces of sheet of the same thickness. However, one sheet may be much heavier if the other is very light. For example, 0.040 inch sheet may be spot welded to one-half inch stock. Three or more sheets of varying thickness may be spot welded together as shown in Figure 3. In this case, thickness of the heaviest piece and the number of pieces in the pack are the limiting factors.

Welding Wrought Metal to Castings:

Wrought sheet may be welded to aluminum castings. Strips cut from 2S, 3S, 17S, 25S and 51S sheet were spot welded to plates cast from the various alloys. Sheets up to 0.064 inch in thickness were spot welded to cast plates ¼ inch thick.

Temper:

It was found that the spot welding characteristics of the sheet were independent of its temper, and that the temper of the sheet surrounding the weld was not materially affected by the heat generated in the process of spot welding. A series of Brinell impressions were made on a number of spot welded joints. The impressions were made on 0.064 inch thick 51SW at intervals of ⅛, ¼, ½, 1, and 2 inches from the edge of the

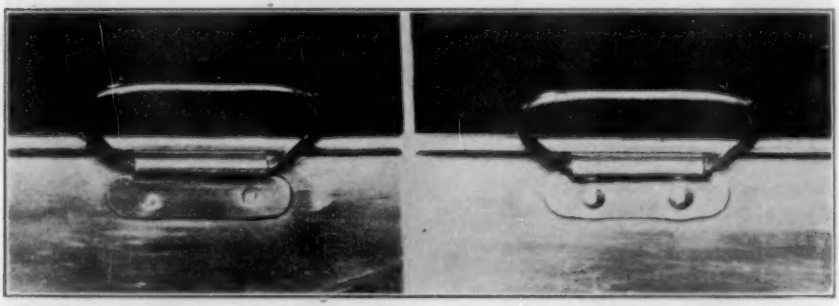


FIG. 5. HANDLE SPOT WELDED ON ALUMINUM PAN

FIG. 5a HANDLE RIVETED ON ALUMINUM PAN

spot welds. The average for a number of determinations gave the following resuts:

Distance from edge of spot.....	⅛ in.	¼ in.	½ in.	1 in.	2 in.
Brinell number	55	60	65	65	65

For normal 51SW the Brinell numbers run from 55 to 70.

Strong Alloys:

Nearly all of the work described has been carried out with 2S and 3S alloys, with only enough investigation of other alloys to learn that they were not materially different in their behavior during welding. However, in considering the spot welding of the strong aluminum alloys, the following should be borne in mind: In the act of spot welding, a portion of the metal at the point of contact melts and solidifies. This area has the structure of a casting, and the joint has mechanical characteristics such as could be expected from a cast rivet. Pure metal in the cast form is relatively ductile. A spot weld of pure aluminum, or 3S, therefore, would be quite tough. The strong aluminum alloys (17S, 25S and 51S), on the other hand, in their cast condition have quite a low elongation and consequently a strong alloy spot welded joint cannot be considered very tough. In other words, it should not be used in places of high stress where the joint is subjected to considerable vibration. We have found

that the spots are clean and sound and that with proper control of current and electrode shape, uniformly good spots can be consistently obtained.

Applications:

A few photographs are shown which illustrate a few definite cases where spot welding may be substituted for riveting or autogenous welding. Figure 5 shows an aluminum pan with the handle spot welded. Four of these pans with the handles riveted, and four with the handles spot welded, were broken in a comparative test. The load was applied so as to duplicate, as nearly as possible, the conditions that would obtain if the

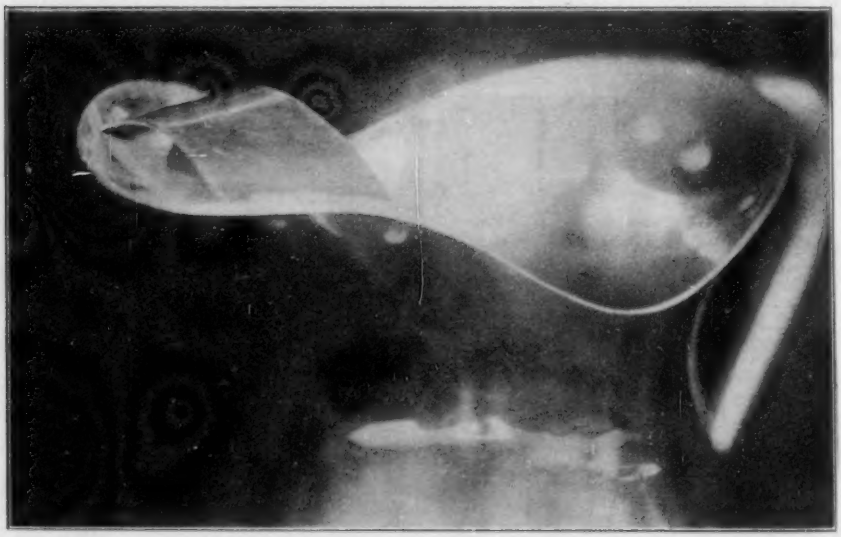


FIG. 6. ICE GUARD SPOT WELDED ON ALUMINUM WATER PITCHER

pan were filled with some substance and picked up by the handles. The handles failed under the following loads:

RIVETED			SPOT WELDED		
Pan No.	Breaking Load in Lbs.	Remarks	Pan No.	Breaking Load in Lbs.	Remarks
1	345	Failed through clip	1	420	Spot pulled out
2	510	Rivets sheared	2	383	Spot pulled out
3	534	Rivets sheared	3	445	Spots pulled out
4	549	Rivets pulled out	4	503	Spots pulled out
	Average 487 pounds			Average 438 pounds	

The difference in strength (50 lbs.) of the two kinds of joint is not large enough to condemn spot welding, especially when it is considered that the strength of either joint is greater than would be needed for the use to which the pan would be put. However, it shows that spot welding does not yield to riveting by any broad margin when the question of mechanical strength is considered.

Figure 6 is an aluminum water pitcher with an ice guard spot welded

in the spout. Fig. 7 shows the tripod band spot welded on a potato-ricer. About 60,000 of these bands have been spot welded during the past few months. These bands were formerly riveted, the rate being 210 bands per day, at a cost of $54.72 per 1,000 pieces. At the present time 700 bands per day are being spot welded at a cost of $34.58 per 1,000 pieces. This shows a very substantial increase in production as well as decrease in cost. These photographs show examples of the application of spot welding aluminum. There are many other articles which could be manufactured from aluminum on a practical scale by means of spot welding, such as filing cabinets, radio shields, metal furniture, various sorts of containers which need not be water-tight, cooking utensils, etc.

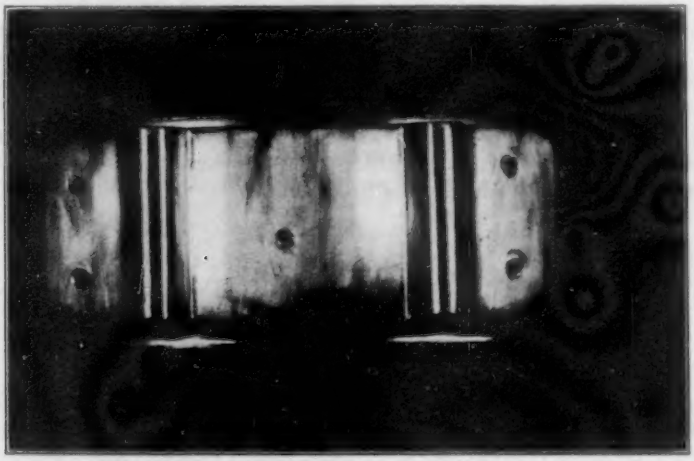


FIG. 7. TRIPOD BAND SPOT WELDED ON NO. 8 POTATO RICER

Advantages of Spot Welding

The greatest advantage of spot welding lies in its cheapness. It accomplishes, in one operation, the same end for which riveting requires three and sometimes four; namely, piercing, countersinking, inserting the rivets, and driving, to say nothing of the manufacturing of the rivets. The spot welded joint is virtually as strong as a riveted joint, while it contains no crevices or corners difficult to clean, nor can it become loose after a period of service. This last is an important item. Rivets have a tendency to stretch and allow some "play" to develop between the parts joined. The spot weld, even if it does stretch, is integral with the two parts, and cannot possibly develop any play. There are many places where spot welding may be substituted for riveting or autogenous welding, with a decrease in cost of making the joint and in improvement in the quality of the finished work.

Conclusions

The contents of this paper have demonstrated that aluminum may be spot welded by essentially the same procedure that is common for other

metals. However, the welding of aluminum is a little more difficult and requires some special precautions. Success in the resistance spot welding of sheet aluminum seems to depend upon the use of a high current for a short period of time. The heavier current required to weld a certain gage of aluminum sheet than for the same gage of steel sheet is made necessary by the higher electrical conductivity of aluminum. The tips of the electrodes must be kept clean and properly shaped. The various parts to be welded should be clamped together in such a manner that good contacts are assured in making the welds. This is essential in all electric spot welding.

Automatic welders should be used, so that the time at which the current is shut off can be closely regulated. Attempts to increase speed on hand or foot operated spot welders have frequently resulted in poor welds, owing to the personal equation varying the length of time in making the weld. Although heat and pressure remained constant, the time element changed more or less with each weld. In addition, speed on a manually operated spot welder where there is a large production has always been accompanied by fatigue. The automatically (air or motor) operated welder insures uniformity in heat, pressure and time and as a result, uniformity in welds and increased production.

Application of Projection and Multiple Welds†

By W. T. OBER*

Advantages of Multiple Welds

Since the discovery of resistance welding, practically all spot welds have been made by using a spot welding machine equipped with two (2) so called pointed copper electrodes or welding dies, the actual size of the point depending upon the thickness of the material to be welded, the capacity of the welding machine used, size of the spot weld required, etc. In this method the pointed electrodes serve as the agent for localizing and concentrating the flow of current to the mass of material directly between the electrodes, and of course, only one spot weld is made for each cycle of operation of the welding machine. Quite a number of years ago it was discovered that by punching a projection on one of the two parts to be welded that this projection would serve as the agent for localizing the current flow, and, therefore, determine the point of weld. Also, that the size and shape of this projection determines to a great extent the size or area of the weld, and thus the strength of the weld. Also, that by using this projection it was no longer necessary to employ a pointed electrode which, of course wears away fairly rapidly, but rather that large flat ended electrodes could be used which would last almost indefinitely.

One other advantage of the use of projections was found to be in the welding of scaly material. Scale or rust is, of course, an insulator and it is often times very difficult to force the necessary amount of current

*Thomson Electric Welding Co., Lynn, Mass.
†Presented before the Affiliated Technical Societies of Boston, Dec. 14, 1927.

for making a weld through this scale when using the ordinary electrode, but by forming a projection on one of the parts, the forming operation breaks up the scale on the projection, and this projection being fairly pointed in turn, breaks through the coating of scale on the other part when pressure is applied through the welding electrodes. For a number of years this method of projection welding was employed only in a small way and no attempt was made to weld more than one projection at a time. As the demand for increased production on welded parts grew, experiments were made to determine the possibility of making several spot welds in one operation. At first these experiments were conducted along the lines of using a series of pointed copper electrodes, but only a fair degree of success resulted, as the same old condition of rapid wear of pointed electrodes was encountered, and as the various points of a multiple pointed electrode did not wear uniformly, a condition was reached after a comparatively short period of operation where due to non-uniform contact between the various points of the multiple electrode and the work, the results were non-uniform welds. Experiments were then conducted relative to the possibility of using large flat electrodes and welding together parts which, instead of having only one (1) projection, had a number of projections. These experiments immediately proved successful.

Applications of Multiple Resistance Welds

It does, of course, require a welding machine of larger electrical and mechanical capacity to make several welds in one operation than is required for making single welds. For this reason and also because of the lack of knowledge of how projection welds could be used to advantage on various classes of work, this method of multiple projection welding was not used commercially to any great extent until comparatively recently. Within the last three or four years our company has designed and developed a number of more or less special welding machines to be used particularly for making multiple projection welds. There have also been developed machines for making multiple welds on parts, the inherent shape or form of which is such that the parts themselves supply their own projections. A typical illustration of this is the welding, in one cycle operation, of a number of wires to one or more wires which cross at right angles, as in wire refrigerator shelves, stove oven racks and articles of a similar nature. Another application of this form of welding is used in the manufacture of grating made from a series of flat rectangular bars stood on edge, to each bar of which is welded in one operation a round or twisted bar laid at right angles to the longitudinal axis of the strips.

This method of projection or multiple welding is being successfully used in the automotive field in the manufacture of various automobile body parts such as door frames, window lifters, four-wheel brake parts, shock absorbers, and on any other article more or less flat or regular in shape and which requires several welds. Experience has taught us that the use of projection welding is not always satisfactory if the part carrying the projection is made from material thinner than 16 or 18 gage, unless the projections are spaced very close together. This is because a pro-

jection punched on thinner material does not have sufficient mass or strength to retain its shape long enough after welding current and pressure are applied to serve its purpose of localizing the current flow.

Limitations of the Method

There is, of course, also a limit to the number of projection welds which it is practical to make in one operation, this limit being determined principally by the area over which the projections or welds are distributed, for as is readily understood, it is necessary that the welding current distribute itself uniformly between the projections or points at which welding is to occur, and that if the projections are spread over too large an area or surface, difficulties will be encountered in obtaining uniform pressure or contact between the large flat surface of the copper electrodes and the work, resulting in non-uniform distribution of current.

In the making of multiple projection welds on sheet metal parts not less than 18 gage in thickness, it has been found that the area over which the projections are distributed should not exceed 30 to 35 sq. in., and that the greatest distance between any two projections in this area should not exceed 10 in. Two to twelve (2 to 12) projection welds on sheet metal parts in one operation are now being made as part of the daily production in many factories. Ten to twenty-five and even thirty (30) welds in one operation are being made on parts of such form that no projection is required, such as wire soap dishes, oven racks, subway grating, in one operation, etc.

The question of whether or not it would be advantageous to use projection or multiple welding on any article now being welded by the single spot method can best be determined by careful investigation of all conditions surrounding the method of manufacture of this article, the production required, the shape and size of the parts and the material from which they are made. The process has a wide field, but is not yet at the point where all of its possibilities or limits are known.

Arc Welded Pipe Lines*

W. L. WARNER†

Introduction

A DECADE ago the idea of conveying liquids or gases by means of continuous tubes was practically unheard of. Today the use of continuous tubes for this service has grown to such an extent that the average layman is beginning to realize the advantages of this type of construction.

The advantages of welded piping over the use of various mechanical joints are generally as follows:

Thinner pipe wall necessary, hence, less material required.
Simple butt joints, no expensive machining necessary.
Full diameter of the pipe effective because no lap joints are used.
Mechanical efficiency of the joint higher than any other type of joint.

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*Presented before Joint Meeting, New York Sections of A. W. S. and A. S. M. E., Jan. 3, 1928.

†Industrial Heating and Welding Engineering Department, General Electric Company, Schenectady, N. Y.

The ease with which the layout and erection are performed is .ommending this type of construction to engineers and industrial managers. A few examples follow:

Steam Lines for Heating Purposes

The increase in the use of steam for industrial heating and power generation in the cities has gradually created a great need for a unified distribution system. In the city of St. Louis, the Union Electric Light and Power Company has been furnishing steam heat to buildings in the business section in addition to its regular lighting and power service for the past decade or more. At first the steam service was supplied from a number of widely separated steam plants, but as the demand increased, additions and improvements were made until in 1916 the first step toward a unified distribution system was taken.

Pressure mains were then laid so that steam could be distributed at 175 lb. pressure. Every year since 1918 the high pressure mains have been extended and some of the isolated steam plants have been joined to the system while some have been discontinued. In 1923 the total length of steam mains was 4½ miles, probably only a small part of which, if any, was of welded construction.

By 1923 the hp. load on the Tenth Street plant had exceeded its capacity, and in order to avoid additional construction in the heart of the business district it was decided to connect the Ashley Street plant, about one and one-half miles away and located on the Mississippi River, to the steam distribution system. The Ashley Street plant contains 56 boilers with an aggregate rating of 30,000 hp., and it was decided that the load factor of this plant would be greatly improved if live steam could be supplied by it to the heating system.

In order to accomplish this result the Union Power Co. had installed something like 8000 ft. of mains during the year 1924. These mains included 3700 ft. of 20-in. pipe, 1245 ft. of 16-in., 945 ft. of 14-in., 1295 ft. of 12-in., and 910 ft. of 10-in. piping.

These mains were installed by the American District Steam Co. of North Tonawanda, N. Y. Some smaller piping was laid, which made it possible to discontinue the operation of five subsidiary steam plants, making a total of thirty steam plants, ranging in capacity from 175 to 500 hp., which have been closed down since 1916, in addition to about seventy-five smaller low-pressure plants.

The high pressure mains are built of extra strong steel pipe ½ in. thick, insulated with 3 in. of high-grade asbestos covering and laid in conduit. The conduit has a concrete base laid on gravel with underdrain tile; the side walls are multicell tile and the top is a slab of reenforced concrete. The details of construction of the joints of the 20-in. high pressure main are shown in Fig. 1. The steel pipe is butt welded with a single V weld and four reenforcing steel straps, 4 in. wide by 8 in. long by ½ in. thick, are welded longitudinally across the butt weld.

The 20-in. main shown in Fig. 1 was built for 250 lb. steam pressure and 100 deg. Fahr. superheat. The steam travels a maximum of 8100

†Industrial Heating and Welding Engineering Department, General Electric Company, Schenectady, N. Y.

ft. from the Ashley Street plant to the most remote customer now being served by the system. The welded main was tested in sections, Fig. 2, to 500 lb. hydrostatic pressure. While under pressure the pipe was pounded with a 2-lb. hammer very sharply on each side of the weld, 2 in. from the weld, throughout the entire circumference of the pipe. Not a leak was found in the 3700 ft. of main.

Expansion joints were placed from 120 to 160 ft. apart and the body anchored to the conduit. The pipe was butt welded to the body of the joint and also to the slip end. No flanged joints were used.

A considerable amount of the welding had to be done in the ditch on account of the traffic congestion on top of the ground in this case. The

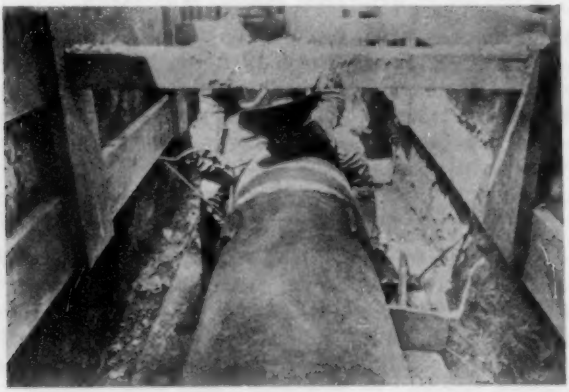

FIG. 1. DETAIL OF WELDED JOINT OF 20 INCH HIGH PRESSURE STEAM MAIN

pipe was rolled wherever possible for the convenience of the welder, but for the tie-in joints between sections the weld was made in place completely around the pipe.

Prior to the construction of the 20-in. main, three types of joint were considered. The welded flange joint of the Van Stone type was rejected because of the expense, combined with the problems of installing the pipe in conduit in the street. Another type of joint considered was one which requires the expanding of one end of the pipe length so that the end of the adjoining pipe length may be inserted about 6 or 8 in., making a tight fit. Holes are drilled in the outer pipe, making it possible to plug weld to the inner pipe.

With this second method of making the joints there appeared to be many construction difficulties. The necessary shop fabrication would increase the cost and the progress on construction would necessarily be impaired. Also, there did not appear to be any great advantage over a butt welded joint reenforced by longitudinal steel strips.

The third type of joint considered was the plain butt welded joint.

and 100 deg. Fahr. superheat. The steam travels a maximum of 8100

Tests on this last type of joint showed the weld to be from 85 per cent to 100 per cent of the strength of the pipe material.

A number of tests were made on the various types of welded joints for this work at Washington University, under the direction of Prof. Sweetzer and these tests were included in a report issued by the Distribution Committee of the National District Heating Association early in 1925.

Steam Lines for Power Transmission

The transmission of live steam for power purposes is essentially no different than for heating purposes. In May, 1925, there was put into

FIG. 2. SECTION OF 20-INCH STEAM MAIN READY FOR 500 LB. HYDROSTATIC TEST

operation, at East Walpole, Mass., a steam line 4550 ft. long to carry steam from the East Walpole plant of Bird & Son, Inc., to their Norwood plant. A general view of the line is shown in Fig. 3.

It will be noted that this steam line was built on a railroad right of way. As it was necessary to keep the pipe at least 8 ft. from the center line of the track, there was not sufficient space available for the construction of U-bents, so that expansion joints were generally used. These joints were of the cross-head guided type with bodies of cast steel and a slip tube of steel copper plated. The maximum traverse of

each tube is 8 in. and they are located 140 ft. apart. The base of each expansion joint is anchored to a concrete pier so that the slip occurs in both directions from that point.

The pipe is 8 in. in diameter with a wall 0.322 in. thick. It was designed to carry steam at 200 lb. pressure with 100 deg. Fahr. superheat, but during the first year operated at 165 lb. and no superheat transmitting 30,000 lb. of steam per hour, twenty-four hours per day.

At the Norwood plant the steam line crosses a railroad and is supported 30 ft. above ground on steel towers. This section is 300 ft. long and terminates in a large U-bend on top of the power house. The U-bend

FIG. 3. GENERAL VIEW OF WELDED STEAM LINE FOR BIRD AND SON

is 30 ft. from center to crown and as it cares for the expansion and contraction of this 300 ft. supported section, it was made this size to reduce the thrust on the anchorage.

Reenforced concrete piers 20 ft. on centers support the pipe, as shown in Fig. 4. There is no noticeable sagging of the pipe between supports.

All joints except those at the expansion joints are arc welded. Each joint was prepared as a 45 deg. single V and welded with a single layer weld around the pipe, as shown in Fig. 5. As the welding of the joints progressed the weld was air-hammered. After welding each joint was annealed in a portable furnace equipped with a kerosene burner.

The pipe line was tested to 500 lb. pressure without a leak. It is insulated with two layers, each 1½ in. thick, of 85 per cent magnesia, and outside of this is wrapped two layers of Bird & Son paroid roofing material. Drips are provided at eight points in the line.

Tests have shown the efficiency of this steam line to be very high. The heat line loss is 2.688 per cent and the pressure drop is about 18 per cent.

Maintenance is limited to the repacking of the slip joints about every

two years. Recognizing its stability, the Hartford Steam Boiler Insurance Co. has insured the line for $100,000.

Originally the steam was generated and used locally at both plants but the cost of steam generated at the Norwood plant was about twice that of the steam generated at East Walpole, due to the fact that the former was much smaller. It became necessary, therefore, to charge the fixed charges on the plant shut down to the cost of operating the pipe line. These costs amounted to approximately 20 cents per 1000 lb. of steam carried by the line. In spite of this handicap, however, the first year of operation has shown a net saving over the cost of operating both plants of approximately 15 cents per 1000 lb. of steam carried

FIG. 4. STEAM LINE FOR BIRD AND SON SHOWING HIGHWAY CROSSING

by the line. Recently the American Car and Foundry Co. has been installing two steam lines, one for low pressure steam to be used for heating purposes and the other for high pressure steam for power purposes in its plant at Berwick, Pa.

The low pressure installation is made up of 8 in., 10 in. and 12 in. pipe of approximately 450 ft., 900 ft. and 350 ft, respectively, the majority of which is carried on steel supporting members from 15 ft. to 20 ft. above grade. All welding was done in place from floor-mounted movable platforms.

The high pressure line of 8 in. pipe is approximately 2000 ft. in length. About 500 ft. is carried underground in a tunnel, the next 700 ft. is carried about 20 ft. above grade along the side of and through the roof trusses of buildings, and the balance of the distance, about 800 ft., is carried 40 ft. in the air on roof trusses of buildings.

Pipe furnished for this installation was standard, full weight, lap welded pipe scarfed at both ends with a 30 deg. bevel for welding. It was found desirable to allow a free distance between scarfed edges of

⅛ in. to secure best results. No metal was used to back up the weld and no obstruction of any movement was noticed on the inside of the pipe. The pipe sections were centered with respect to each other by means of a collapsible jig. This jig was fitted with a bend on one end, used to slip over one end of the pipe, and adjustable fingers on the other end. By means of this apparatus it was possible to easily line up the pipe and have sufficient space for tack welding.

The section of pipe in the tunnel was easily accessible and could be turned for the welding operation. The remainder of the line was welded in place without turning, due to its suspension in hangars. Under 100 lb. pressure test the section in the tunnel was absolutely tight. In the

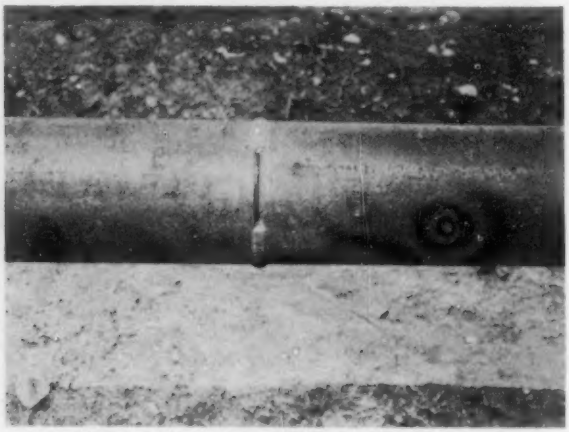

FIG. 5. DETAIL OF ARC WELDED JOINT OF STEAM LINE FOR BIRD AND SON

remainder of the line, which was supported over 20 ft. above ground, about ten leaks developed under pressure. All of them occurred at the bottom of the pipe joint probably due to expansion of the pipe and inexperience of the operator. Repairs were made by chipping out the leaky spot and rewelding.

Both pipe lines were provided with expansion joints. The installation was done under the direction of Mr. M. S. Evans, superintendent of maintenance, of the above plant.

Water Pipe for Municipal Water Supply

With the growth of our cities comes the ever increasing demand for an uncontaminated and adequate water supply. In many cases it is necessary to locate the source at considerable distance from the center of population, which requires bringing the water by a pipe line to the ultimate consumer.

About two years ago the city of Vallejo, Cal., was faced with such a problem and it was decided to build a reservoir in the foothills about

22 miles away, from which the water would be brought to the city mains by means of a pipe line. Accordingly the contract was let and the pipe line installed by the Western Pipe and Steel Co. of San Francisco, Cal., using the arc welding process.

The line is 24 in. in diameter and was constructed of 3/16 and ¼ in. plate, cut to size and rolled into 14 ft. lengths. All longitudinal seams were automatically arc welded in the shop and after this operation two 14 ft. lengths were butt welded with the arc end to end to form a 28 ft. length. Immediately upon leaving the automatic welding machines each length was closely inspected for possible flaws, after which it was submitted to a hydraulic test to 225 lb. pressure.

The pipe line operates under a static head of from 100 to 400 ft. (45 to 175 lb.). Each 28 ft. section was dipped in hot asphalt and wrapped with several layers of impregnated felt for soil proofing. The pipe sections were then transported to the site and distributed along the ditch.

Four of these pipe sections were welded together on top of the ground to form a length 112 ft. long between the bell hole joints. The handling of the individual lengths was facilitated by the use of a caterpillar crane.

For the information of the engineers several of the 14 ft. sections were tested in the shop to 325 lb. pressure and a few were tested to 720 lb. No leaks were found on these tests.

There were a total of 8200 girth seams in the whole line, half of which were field welded the other half being welded in the shop. After completion of the line a service test was made prior to acceptance by the city and the line was put into operation immediately.

Gas Pipe Lines

The use of arc welding for laying gas mains has also received some attention as certain advantages are obtained over the older types of joints, such as the screwed and flanged joints. The welded joint requires practically no shop work and although bevelling is sometimes done it is by no means always necessary. Also, welded joints are tight when completed and require no caulking when properly made. The welded line can be put together on top of the ground and rolled into the ditch. This procedure eliminates a considerable amount of ditch digging, which is quite an item in some localities.

For the past two years the Consumers Power Co. of Pontiac, Mich., has been using arc welding for this work, and during the latter part of 1925 installed about 7 miles of 6-in. pipe for conveying gas at 60-lb. pressure. The thickness of the pipe wall was 5/16 in. and each joint was bevelled at 30 deg. for a single Vee weld. The pipe lengths were 40 ft. and expansion joints were placed every 1500 ft. The pipe was welded on the surface beside the ditch, which varied from 2 to 6 ft. in depth and then was rolled into the ditch after the welding was completed. The completed line was proof tested and each joint was hammered while under pressure to develop any weak spots. These, however, failed to materialize.

In the foregoing discussion it has been the writer's purpose to show

that the electric arc welding process is seriously regarded as a dependable and efficient tool for the joining of steel piping. The procedure used and the welding technique employed will vary considerably depending upon the nature of the job and the personal viewpoint of those in charge of the work. The question of acceptance tests is also important but the time allowed does not permit of a discussion of this subject. It may be said, however, that there is yet no standard for welded piping although in certain localities tentative codes are in existence.

One final point the writer wishes to make in closing is in connection with the requirements for welded joints as compared to the older types of mechanical joints. Experience has taught certain things, i. e., we may expect a certain mechanical efficiency from a certain type of joint, be that what it may—50, 60, 75 or even 100 per cent. Knowing this we design on that basis. But, 100 per cent efficiency is expected of the welded joint every time. This is really good for welding, fundamentally speaking, but rather irritating at times. Safe design values, factors of safety, and design formulas may be used for welded construction in the same way as with other methods if we but understand them. And it is a safe bet that any weld, properly made, with the right kind of materials, will stand the tests of service and last forever, yea, unto the end of time.

Welding as Associated with the Handling of Petroleum Products*

By F. C. FYKE†

Applications of Welding Growing Steadily

WELDING, like riveting and other applications of mechanics, cannot be said to be the most suitable means for fabricating every class of equipment, without first giving some thought to the design and working conditions to which it will be finally subjected. Experience has shown that riveted type of construction on certain kinds of equipment can be advantageously replaced by welding and likewise this can be said of welding. They both have their fields in which they are most suited, but, like any departure from along lines of accepted engineering practice, some time and concrete facts are required before new methods gain much momentum in the industrial world.

When speaking of welding herein, all kinds of welding are implied rather than any particular one phase of the art. Although it is a recognized fact that the fields for the various kinds of welding do overlap. In some instances there are some which are limited to more specific fields. The welding industry as a whole should be pleased with the stride and success that it has attained during the past few years and with its prospects for a sound future. If consideration had been given only to the volume of welding that was possible and not to the satisfaction that is

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manifested from work being properly performed, probably the volume of welding itself would have been materially increased. If one stops to consider, however, the detrimental effects which might have resulted by following the optimistic viewpoint of some of the promoters of the art, the results would have retarded the growth of the industry as a whole rather than developed it. This conservative attitude, while subject to criticism in some respects, has been a good thing toward bringing about a healthier growth in welding, as is feasible and to be expected in any new engineering undertaking.

It may be said that conservatism toward welding is particularly noticeable in the handling and refining of petroleum products. This is to be expected as the very nature of these products is such as to make it necessary that all construction work be carried out in an unquestionable manner, rather than have any part in doubt, where loss of life and property may result. On the other hand, the petroleum industry has accepted welding very enthusiastically and a surprising number of different applications are being made of it throughout, from the producing of the crude to the sales of the finished products. While it will not be attempted to mention them all in this paper, they have all resulted in obtaining either a more economical construction, better product, or a combination of both.

A greater volume and broader field undoubtedly would have resulted had there been available more approved data for the guidance of the industry. The lack of such information for all industries is doing more than the reluctant attitude of the public toward preventing the art from reaching a higher state of development.

Welded Pipe Lines

Considering the applications of welding to the petroleum industry, as a whole it is best to start in the producing fields where the crude is obtained and follow through to the refined products. The largest application in the fields is in the oil and gas pipe lines through which oil in many cases is transported from the Western and Southern fields to the Eastern seaboard. While welded construction is a relatively new method, it is gaining in magnitude, and the following are a few salient features to consider in the construction of any pipe line:

Cost of Installation.
Speed of Laying.
Maintenance.
Advantages.
Investment.

Cost and Speed of Welding

The initial cost of a welded line may be slightly less than the threaded and coupled but the difference is small and hardly worth considering. In fact, some figures have been procured on welded lines which have shown the initial cost to be slightly higher than the threaded and coupled. This will vary with the climate and geographic conditions of the country in which the line is being laid. It may be said that by using double lengths

the cost will be reduced. This is true in the welding alone, but there is additional expense in the purchase and handling of the double lengths, which largely offsets the saving effected in welding. This would be more noticeable in foreign countries where the handling of double lengths would be very expensive and practically impossible.

The speed of laying is probably more important than anything else in the construction of any pipe line, be it either for oil or gas transportation. These lines are not usually started until urgently needed through the sudden development of some field. This necessitates some immediate means of getting the oil to storage. In addition, the early operation of a line results in an early return being realized from the investment. From both of these angles the importance of speed in pipe line construction is obvious, and this is probably the only objectionable feature to the welded line, for experience to date has not shown that the same speed can be obtained in laying a welded line as is possible in a threaded and coupled line. This is largely due to the difficulty of assembling, organizing and placing the required number of suitable welders on the line at different points. This difficulty becomes more pronounced in isolated countries. An example of the importance of speed may be cited in the case of a recent line of about 400 miles which was specified to be all welded. Soon after the laying was underway about 70 per cent of the order was changed to threaded and coupled, due to the progress made in welding the line.

Advantages of the Welded Line

The initial tests on welded lines have revealed very few leaky joints, which is later manifested in a low maintenance cost. In some instances the pressure drop has been as low as one-half of 1 per cent over a period of thirty minutes at 800 lb. to 900 lb. per sq. in. On some relatively short lines no drop whatsoever has been indicated. This is highly commendable and one of the advantages of a welded line over a threaded and coupled line, where the line drop may be as much as 10 per cent and which is aggravated by collar leaks after the line is in operation. The tightness and soundness which is obtained in a welded joint has made it possible to eliminate the customary line-walker, who is still used on screwed lines.

The following are some of the outstanding features of a welded line:

Work can be carried on simultaneously at a number of different points along the line.
No loss from damaged threads.
Pipe through the joint is easier to bend.
Ease with which repairs can be carried out.

The above is applicable to the branch and gathering lines as well as the main trunk lines.

Welded Manifolds and Connections

In the manifolding and connections around the pumping stations, as well as in the tank farms, welding has proven to be not only a time saver but a sound investment when considering the saving affected over

the use of cast fittings. This particular phase of the transportation system has offered exceptional opportunity for a very varied application of welding and the results obtained have been gratifying.

While the larger percentage of the welding on pipe lines has been by the gas process, the fact remains that some has been done by the electric process, with equally satisfactory results, and the indications are that this process offers the only means of eliminating the one already mentioned objectionable feature to a welded line, i. e., the speed of laying.

Welding in the Refineries

Following the transportation through to the refineries where the different products are made, we here find the greater volume and different applications of welding. The nature of the construction and operating conditions is such that all precautions must be taken in order that the installation will be dependable. The trend at present toward what might be said to be more severe operating conditions makes this highly necessary and presents problems far more difficult than those encountered in high pressure utility plants and distribution systems. Hence, the reluctant attitude taken in some instances in the past toward welding.

As already mentioned, it would be impossible to cover in detail all the different applications of welding having magnitude and importance in the refineries. It is well, however, to mention briefly some of these, in addition to the several specific cases which will be taken up later in detail. Welding is being used not only in the caulk welding of riveted pressure and vacuum equipment, but in making the complete joint itself. Types of work consisting of coils, manifolds, tank bottoms, roofs and shells, piping, flanged joints, lining of vessels, structural supports, repair to mechanical equipment, etc., in addition to many others, have all been practical from a standpoint of both design and service.

Welding of Storage Tanks

One of the recent applications of welding, which will be described in detail, was the construction of four 15 ft. x 24 ft. high tanks for the storage of light oils and alcohol. The importance which these particular tanks hold with the welding fraternity is in the type of joint used and the service obtained since erection. It will be recalled that at the fall meeting held in Detroit in 1927 there was considerable discussion regarding butted joints for tank construction. At that time it was the strong feeling of some members of this Society that his type of joint was entirely unsuitable for this purpose. The closing remarks were to the effect that the arguments presented were of little merit and not substantiated by facts that this type of joint if properly made would be satisfactory. In the detail of the construction of these tanks it should be noted that the butted joints were not beveled in any way.

After planing to a square edge, the shell plates were crimped and rolled in the regular manner, special care being taken so as to have all plates of the same radius. The bottom and shell plates of each tank were of ¼ in. steel, the roof being 3/16 plate. The bottom consisted of three pieces, the roof four pieces and the shell of four courses made up of three sheets each. The shell plates were planed to a square edge on

all four sides and to the exact dimensions necessary to obtain the proper diameter and height of the tank. Six plates were planed at one time, the amount planned off varying from 3/8 in. to 1 in. The curved edges of the bottom and roof sheets were sheared to size and the straight sides planed. The bottom was made 2 in. larger in diameter than the shell to allow for proper fitting of the shell to the bottom. The pitched roof was made so as to have an overhang of about 1½ in.

The welding was done with a D. C. arc welding machine using a voltage of 18-20 and an amperage of 140-150 amps. across the arc, depending upon the size of the rod and thickness of plate. The welding wire used was 1/8 in. and 5/32 in. uncoated rods. All the joints on the bottom and both the vertical and horizontal joints in the shell, were butted, using a 3/8 in. bead on the inside and a 1/4 in. bead on the outside. In making the butt welds the edges of the plates were held 1/8 in. apart by inserting washers or spacers between them so as to allow for a thorough penetration of the weld. The roof sheets were lapwelded, the plates overlapping 1 in. and the seams welded on the outside only with a 1/4 in. bead. The joint between the shell and bottom was effected by placing the shell sheets on the bottom plates and welding on the inside and outside 1/4 in. and 3/8 in. fillet welds, respectively. The connection between the roof and shell was similarly made, being welded outside with a 3/8 in. bead and tack welded inside about every 12 to 15 in.

Welding the Bottoms of Tanks

In welding the bottoms of the first two tanks the plates were placed and held in position in a hydraulic press to prevent buckling. The manner of holding the plates was later changed to avoid the use of a press and thus prevent any delay on other work. This was accomplished by using two H-beams, one directly over the other, and held about 24 in. apart by spacers welded to each end. The plates were placed on the lower beam and held in place by pieces of wood wedged between the plates and the upper H-beam. When securely fastened, a 2 in. tack weld was made in the center and at each end of the joint and afterwards completely welded by using the back step method. After completion of one side the bottom was turned over and the other side welded.

Welding Sides of Tanks

After completing the bottom, two circles were laid out on the surface indicating the exact position of the bottom shell course. C-clamps were then fastened to the bottom, about 3 ft. apart around the circumference, to act as guides when placing the shell in position on the bottom. The first shell course sheets were held metal to metal on the bottom by means of a sling hooked over the top edge of the shell plate and a bar under the bottom and tack welded. Before the last vertical seam of the first course was tacked the circumference of the upper edge was measured and a wedge inserted to obtain the correct circumference. The second course shell sheets were similarly placed in position on the floor and the vertical seams tacked and welded. The second course was placed by a crane, on the first course and held in position for tacking by means of the rigging. This rigging was not removed until sufficient tacks were made to hold the sheets securely in position.

Welding Roofs

The two halves of the roof, which consisted of two plates, were tacked and welded under the hydraulic press, similarly to the bottom. Here, of course, as previously stated, lap welds were made, using a ¼ in. bead outside only. The two halves were placed in position on the floor and the center blocked up to give the roof a pitch of ½ in. to the foot. In this position the roof plates were tacked and welded, using the back-step method.

The procedure explained above for the welding of the first and second courses to the bottom was followed in assembling the third and fourth courses and the roof. The roof, of course, being placed upside down on the floor. As aforementioned, the joint between the fourth course and the roof was welded with a ⅜ in. bead outside and only an occasional tack weld on the inside.

The top half of the tank was then lifted and placed in position on the lower half, the two sections being held for tacking by the rigging previously mentioned.

The roof of the tank was supported by nine 3 x 3 x ⅞ in. angle iron rafters welded to a ⅜ x 36 in. rafter plate in the center of the tank and the outer ends bent down 10 in. and welded to the shell plates. In place of the regular king post a piece of 3 in. pipe approximately 2 ft. long with a flange on one end was used. The flange was welded to the rafter plate and the other end of the pipe welded to an 8 in. I-beam placed diametrically across the fourth shell course and welded to it. In addition, the I-beam was supported by two 4 x 4 x ½ in. angle iron clips welded to the shell. Two 1¼ in. forged steel eye bolts were inserted through the roof and fastened to the rafter plate, to serve as a means of lifting and handling the tank.

Each tank was equipped with one 20 in. roof manhead welded outside only and one 24 in. shell manhead welded inside and outside. The inlet and outlet connections consist of two 2 in. and two 3 in. couplings inserted half way through the shell and welded inside and outside. A draw-off pan was welded inside and outside to the bottom of the tank. A ½ in. bead was used for welding all of these connections.

Inspection and Testing of Tanks

The large weld of each butted joint was inspected before the small weld was made on the opposite side in order to determine the amount of penetration and the visible character of the weld. When the tank was completed all welds were examined for cracks and quality of weld, by visible means.

The tanks were filled with cold water for test, enough water being run in to cover the joint between the fourth course and roof. When filled the seams were struck at various places with an 8-lb. hammer. All of the welds withstood the test and no leaks were noted.

Welded test pieces were made up under the same conditions as the welded tank. These pieces consisted of both butt and lap joints, using the same size weld as was used in the tanks. All of these pieces were

subjected to tension, bend, torsion and impact tests. Taken as a whole, the results of these tests were entirely satisfactory.

The fabrication of these tanks was followed from a standpoint of both cost and construction and a material saving in the welded tanks was found. Very few difficulties were experienced in the fabrication when considering that these were the first tanks to be so constructed, and it is believed that any confusion that did result would be eliminated on future installations.

Welding Drip Pans

Another piece of welding which was a decided departure from riveted construction, was in the fabrication of a so-called drip pan, which is used in connection with the process work. This pan, which was 20 ft. x 25 ft. x 5 ft. high, was electrically arc welded and is used for collecting paraffin drips. In service the pan is set into the ground, only the roof protruding above ground. It is obvious that tight joints are required and to this end welded construction was used.

The bottom and shell were made of ⅜ in. and the roof of 5/16 in. tank steel. The joints of the shell and bottom were butt welded and those of the roof were lap welded. All plates were sheared to size. The bottom plates were beveled at the edge where they butted against one another so that a V weld could be made at the joints. This is a somewhat different joint from that used in the tanks just described, due to the use of heavier plates.

The bottom was welded, using a ½ in. bead outside and a ¼ in. bead inside. The butted shell plates and the joints between the shell and the bottom were welded, using a ⅝ in. bead outside and a ¼ in. bead inside. The roof was welded to the shell, outside only, using a ⅜ in. bead. The roof plates were lapped and welded, outside only, with a ⅜ in. bead. The roof plates were lapped and welded, outside only, with a ⅜ in. bead.

Only one fixture was used in connection with the welding of this pan. This consisted of two H-beams held directly over the other about 24 in. apart by a spacer welded at each end. The fixture was used for holding the bottom plates in position to prevent buckling while they were being welded. The ends of two adjoining bottom plates were laid on the lower H-beam and held in position by wedging cut timbers between the plates and the upper H-beam. The plates were tacked and the weld made by the back-step method.

The supporting members in this pan consisted of a 10 in. I-beam, along the entire length at the middle of the roof, welded at each end to the shell plates. The 10 in. I-beam is supported by three 6 in. I-beams welded to the 10 in. eye and to the bottom of the pan. Six 6 in. channel beams were used as rafters. These were equally spaced along the roof, three being used on each side. The channel beams were welded to the web of the 10 in. I-beam and to the side shell plates. All welding on the roof supports consisted of a ⅝ in. bead.

Four hatchways were welded on the roof, using a ½ in. bead on the outside only.

The pan was tested by filling it with water and striking the joints with an 8-lb. hammer. All welds withstood this test and no leaks were noted.

Welding of Vacuum Towers

A third application, which was somewhat different from the other two just described and unique in that it is subjected to vacuum under operating conditions rather than pressure, was in the fabrication of a number of towers for vacuum equipment. Tightness is, of course, of major importance in this class of equipment and welding was resorted to in order to minimize the possibility of leaks. Two of the towers were 12 ft. x 24 ft. high and two 10 ft. x 30 ft. high. The shell plates and heads of all towers were made of ¾ in. plate.

These towers were designed for vacuum service and were therefore equipped with a special shaped head designed for use in connection with vacuum towers. The bracing in these towers consisted of 6 in. channels spaced 2 ft. apart throughout the tower. These channels were rolled to the inside diameter of the tower and the heel welded to the shell around the entire circumference. The butted ends of the channels were then welded in place. In addition, the towers were also afforded bracing by the flat plates with which they are equipped on the inside. These plates were ¾ in. thick and were of the same diameter as the inside of the tower, and were welded to the shell around the circumference. They were supported by 6 in. channels placed across and under the plates and welded to the shell.

Special bracing was made at the butted joint of the head and shell. A 6 in. H-beam was rolled to the inside diameter of the tower and placed so that one flange would brace the head and the other flange brace the shell; in other words, the H-beam was placed so that the butt joint would come in the center of the web of the beam.

All joints of these towers were double V butt welded, with an electric arc, using 5/32 in. bare wire. The welding was done with 165 amps. and 20 volts across the arc.

The 12 ft. x 24 ft. towers were made of two 12 ft. shell courses and the 10 ft. x 30 ft. of three 10 ft. shell courses. The plates were beveled on all four edges on the planer and rolled to the proper diameter. The longitudinal welds were then made. Four-in. tack welds were made about 18 in. apart on the longitudinal seams. One bead was then laid along the entire length of seam on the inside and outside. Whenever a crater was left in the weld due to starting and stopping, the surface was chipped off. Both beads were then bobbed with a roughing tool and the finishing bead welded on, building up the joint about 15 per cent thicker than the plate for reinforcement.

The courses and heads were assembled and held in place by tacking and then welded by the same procedure as explained above for the longitudinal seams.

While in the construction of the equipment just referred to it will be noted that the butted joint was employed in each case, it should be mentioned that each was different in that one was square, one single

beveled and the third double beveled. The satisfaction that has been obtained since this equipment has been placed in service does not substantiate the contention already referred to that butted joints were not suitable for tank and drum work.

Standardization Needed

While an attempt has been made to show in a way what is being done with welding as associated with the handling of petroleum products, there are many more uses, some of which are of such magnitude and importance as to warrant having individual papers devoted to them. While you may have some conception of the work that is being done, yet it is believed that the surface of the usefulness of welding has only been scratched. The lack of publicity along the lines of recognized standards of procedure, design, strength and size of welds, and materials, has retarded a greater and broader application of the art. For instance, how many people at present order welding wire in accordance with the specification of the American Welding Society? Most of it is purchased according to some manufacturer's trade name, yet it may be in accordance with one of the Society's specifications. It would be much simpler and far more satisfactory to the consumer to have welding wire known as and made to some standard specification. Much prestige would be given the American Welding Society, as is enjoyed by some of the other leading societies, where their particudar specifications are referred to in the ordering of steel, as well as the mentioning of various codes in the fabrication and erection. To this end the manufacturers could do much toward bringing this about, rather than pushing a special trade name.

Standards toward size, design and strength would do much toward furthering the intelligent use of welding. Statements to the effect that certain welds are strong enough for a particular working condition are an indication and a breeder of carelessness and have no merit. There should be a certain strength established for a weld, the same as now exists for rivets. The cross section could then be calculated, depending upon the strengtfh desired, as is done in riveted construction where the size and number of rivets are considered when figuring a riveted joint. This would be more along the lines of good engineering practice than to say that a good weld is essential in one place and a poorly made weld will answer the purpose elsewhere.

Another problem in which industries confronted with corrosion are very much concerned with is the welding of corrosion-resisting alloys, particularly those of the chromium group. While this class of material offers an excellent field for combatting corrosion, industries are awaiting information as to how it can be satisfactorily welded.

While some of the points mentioned here may have been touched upon by the author in a paper presented before this Society several years ago, it is still believed that any sound work done along the above-mentioned lines will be manifested in a greater and healthier growth of the welding industry and the Society fostering this art.

Static and Impact Tests of Electrically Welded Joints

By PROF. RAYMOND J. ROARK†

DURING the winter of 1924-25 a number of tests of electrically welded joints were made at the University of Wisconsin by Mr. F. L. Weeks, in connection with the preparation of a thesis for the degree of master of science in civil engineering. These tests, which were carried out under the general direction of the present writer, were intended to form part of a more extensive study of structural welding. Owing to unavoidable delays in the continuation of this investigation it is believed that the publication at this time of the results of these tests is advisable, and they are presented, in condensed form, in this paper.

Purpose of Tests

The primary purpose of these tests was to secure information as to the strength and uniformity under both static and impact loading of fillet-welded joints, i. e., joints made by lapping the parts to be connected and then welding along the edges of the surfaces in contact. Such joints are adapted to use in structural steel work. Since the main stress on the weld is shear, the tests provide information as to the shearing strength of welds made in the manner and of the materials employed in the preparation of the specimens used.

Test Specimens

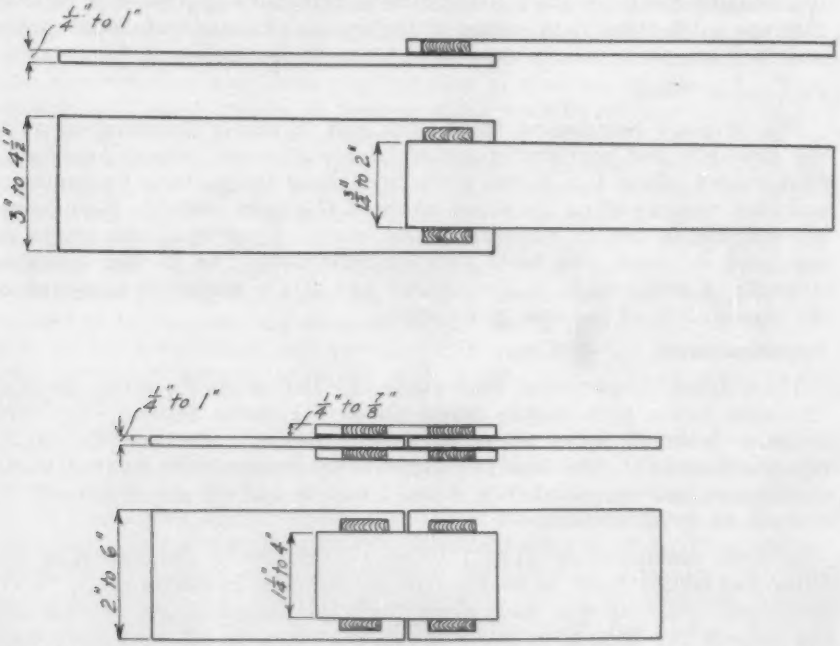
Three types of specimens were used: (1) Lap joints for static testing; (2) butt joints with double splice plates for static testing; (3) butt joints with double splice plates for impact testing (also used for duplicate static tests). The first two types of specimens, with their limiting dimensions, are represented in Figs. 1 and 2, and all are illustrated in Figs. 3 to 9, inclusive.

In some specimens of Type 1 (Nos. 1-9, inclusive) the length of the fillets was simply made as nearly 1 in. as possible; in others (Nos. 10-17, inclusive), the weld was made along the whole length of the overlap and the ends of the bars then milled away exactly 1 in. of weld remained; in still others (Nos. 18-21, inclusive) the bars were lapped 2 in. and the welds made and left along the full length of overlap.

In some specimens of Type 2 (Nos. 22, 29 and 30) the main bars were simply placed end to end and the splice bars welded in place along their longitudinal edges, the lengths of the welds and dimensions of the plates being varied in order that information might be secured as to the effect of such variation on unit strength. In other specimens of this type (Nos. 37, 38, 39 and 40) the main plates were separated by a thin transverse strip of insulating material to prevent direct butt welding of their ends, and the 2 in. splice plates were welded along their entire length, afterward being cut back till they extended exactly ½ in. on each side of the joint. The fillets were then sawn through in the plane of the joint to eliminate their action in tension and to make the stress in the weld a purely shear stress.

†The University of Wisconsin, Madison.

The specimens of Type 3 (Nos. 1-I to 11-I, inclusive) were made in practically the same way as those last described, differing only in dimensions. These specimens are illustrated in Figs. 7 and 8. The ends of the main plates were turned down and threaded to permit of testing in the Russell impact machine, in the manner described below. Duplicate specimens exactly like these impact specimens, except for the greater length of main plates, were prepared for static testing (Fig. 9). For purposes of comparison, riveted butt joints as nearly as possible equivalent in form and strength to the welded impact specimens were prepared. The specimen labeled R1-I, Fig. 9, is of this type.



FIGS. 1 AND 2. SKETCHES SHOWING DESIGN OF SPECIMENS USED IN TEST PROGRAM

All specimens were electrically welded, metal electrodes being used. All specimens except Nos. 10 to 21, inclusive, were donated by the Vilter Manufacturing Co. of Milwaukee. In welding them, 5/32 in. uncoated electrodes with 160-165 amperes and single layer deposit were employed for ¼ in. and ⅜ in. fillets; 3/16 in. uncoated electrodes with 200 amperes and double layer deposit were employed for ½ in. and ¾ in. fillets, and ¼ in. uncoated electrodes with 200 amperes and double layer deposit were employed for 1 in. fillets. The welding rods used met the requirements of the S.A.E. specifications No. 1015 (carbon, 0.10-0.20 per cent; manganese, 0.30-0.60 per cent; phosphorus, 0.045 per cent max.; sulphur, 0.05 per cent max.).

Specimens Nos. 10 to 21, inclusive, were prepared and donated by the General Boilers Co. of Waukegan, Ill. In preparing these specimens

steel welding rods and plates were used that met the requirements of the rules of the American Society of Mechanical Engineers for the construction of low pressure heating boilers (carbon, 0.12 per cent; manganese, 0.06 per cent; phosphorus, 0.04 per cent; silicon, 0.08 per cent; sulphur, 0.04 per cent, yield point 42,000-55,000 lbs./sq. in.) In welding these specimens ¼ in. uncoated electrodes with 200 amperes and single layer deposit were employed.

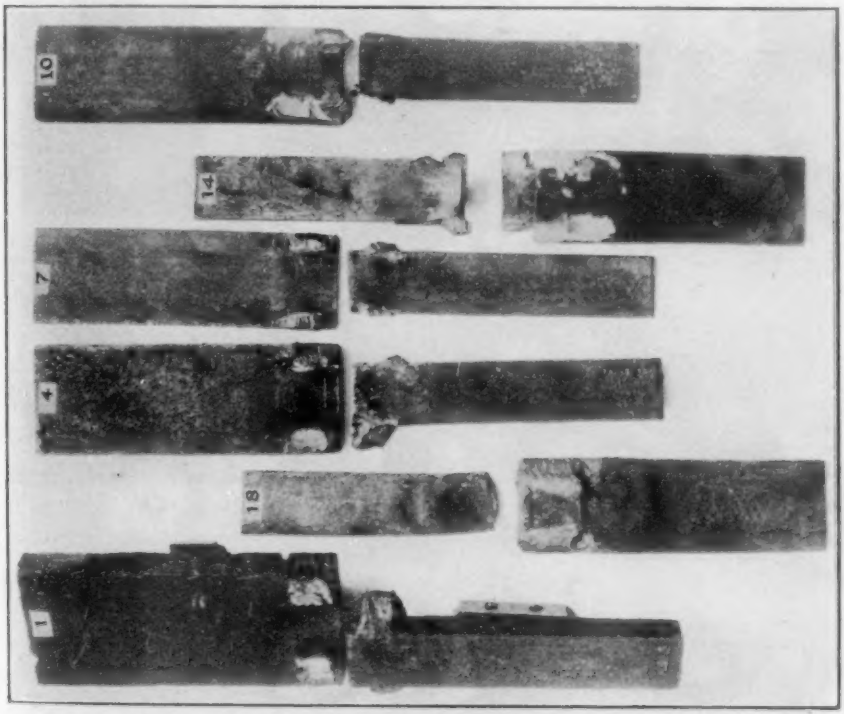


FIG. 3. LAP JOINT SPECIMENS

Method of Testing

Two Riehle Universal machines were used in making the static tests. For the narrower specimens a 100,000 lb. machine was used, the speeds employed being 0.055 in. per minute up to 10 per cent (estimated) of the breaking load and then 0.027 in. per minute to failure. For the wider specimens (above 3 in.) a 200,000 lb. machine was used, the speeds employed being 0.06 in. per minute up to 10 per cent (estimated) of the breaking load and then 0.32 in. per minute to failure.

The following data were recorded: The load at which scale started dropping from the joint (hereafter referred to as the "yield point"); the ultimate load; the stretch of the joint determined by measuring the distance between lines scribed on the wider bar along the end of the narrower bar at zero load and at the maximum load (hereafter referred to as the "elongation").

Impact tests were made with the Russell impact machine. This machine is of the pendulum type and measures the energy expended in breaking the specimen. It consists essentially of a heavy pendulum in the form of a flat bar, which swings freely on a horizontal axle through one end. In making a test the specimen was screwed into a hole tapped into the rear edge of the pendulum and was provided with a "hammer," a short, stiff bar screwed to its other end and set transversely to the plane of the pendulum and specimen. Two supports or "anvils" were

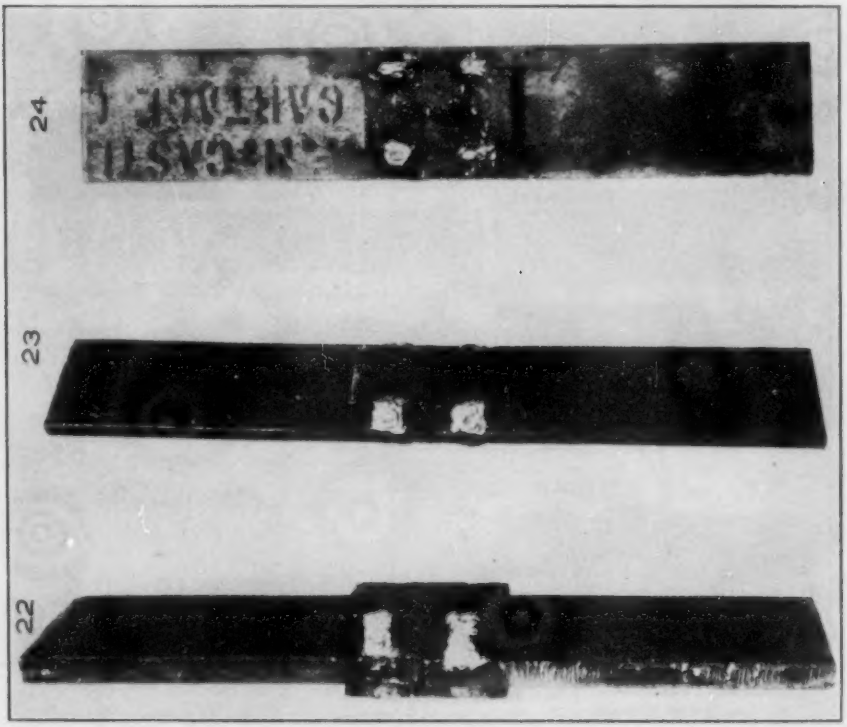


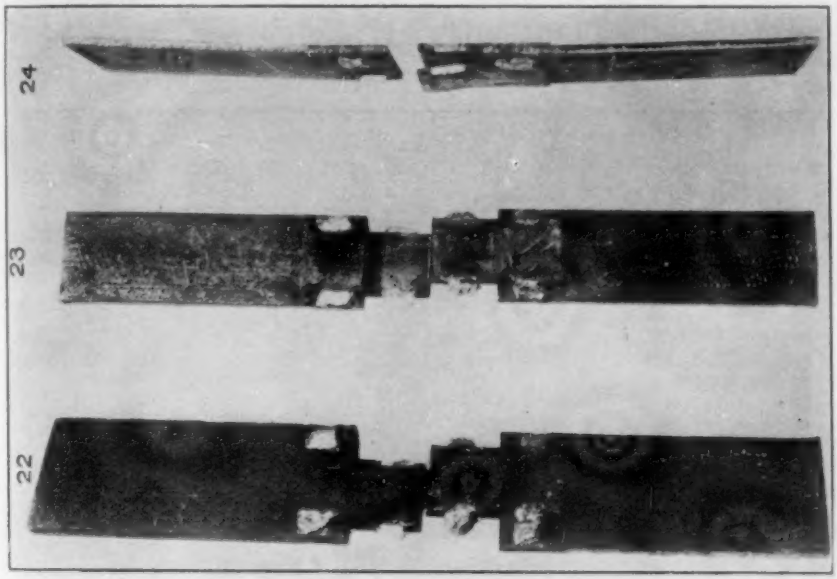
FIG. 4. BUTT JOINT SPECIMENS

provided, these being adjusted so that the pendulum, but not the hammer, could pass between them. When the pendulum was raised and allowed to swing the hammer struck the anvils and the blow, transmitted to the specimen as a sudden tension, broke the joint. The difference between the initial elevation of the pendulum and the angle to which it rose after impact afforded a basis for the calculation of the energy expended in breaking the specimen.

Results

The results of the static tests are presented in Tables I and II. Specimens of the same type are grouped and only the average results for each group are given. The maximum variation of the strength of any

one specimen from the mean for the group indicates the uniformity of the results. Values in the column headed "lbs. per sq. in." were obtained



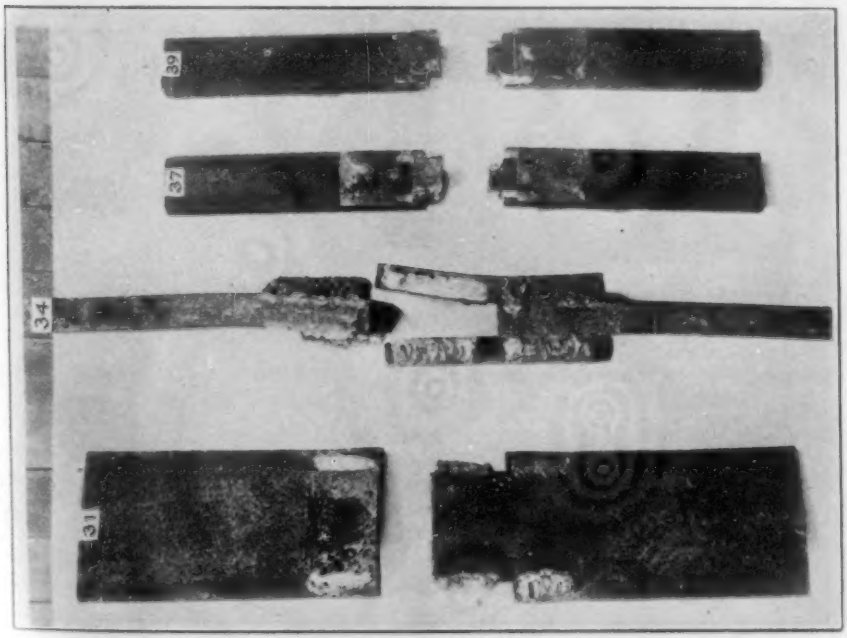


FIG. 5. (UPPER) AND FIG. 6. (LOWER) BUTT JOINT SPECIMENS AFTER TEST

by dividing the breaking load by the area of the sheared surface of the weld; values in the column headed "lbs. per linear inch" were obtained by dividing the breaking load by the total combined length of fillets in the case of the lap joints, and by the total combined length of fillets on one side the joint in the case of butt joints.

The results of the impact tests are presented in Table III. Values in

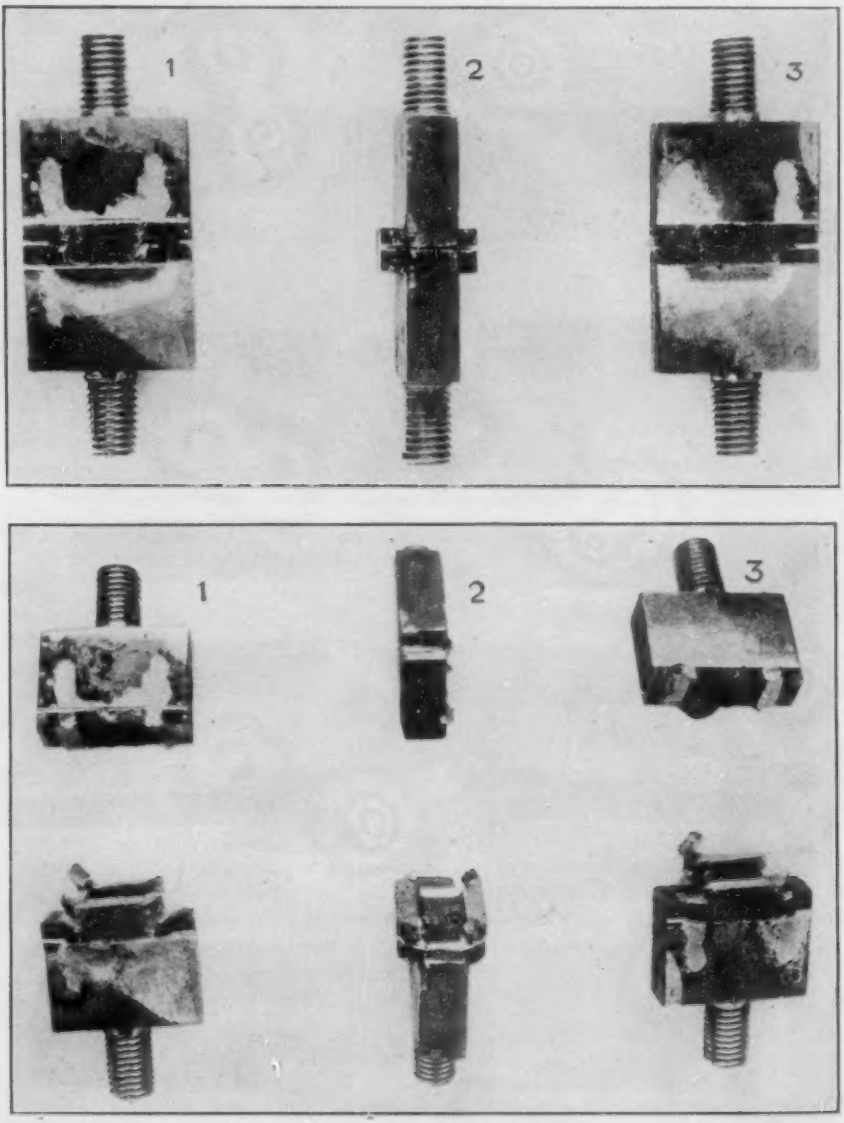


FIG. 7. (UPPER) AND FIG. 8. (LOWER) SHOCK TEST SPECIMENS BEFORE AND AFTER TESTS

the column headed "Estimated static strength of specimen" were obtained by multiplying the static strength per square inch of duplicate specimens tested statically by the area of the weld of the specimen in question. The values in the column headed "Calculated ratio of impact strength of welded specimen to impact strength of riveted specimen of same static strength" were obtained as follows: Three riveted specimens were tested in impact, and three similar riveted specimens were tested statically. The average energy of rupture was found to be 553 in. lbs.; the average static strength was found to be 4300 lbs. The ratio of the

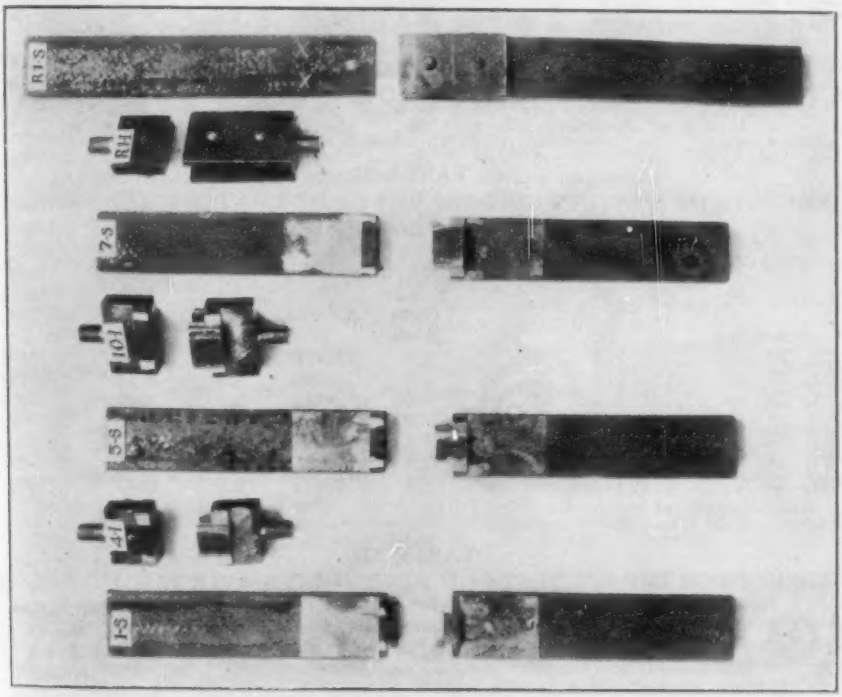


FIG. 9. COMPARATIVE RIVETED AND WELDED SPECIMENS

impact strength of a welded specimen to that of a riveted specimen of equal static strength was then assumed to be given by

$$\text{ratio} = \frac{\text{energy of rupture of welded specimen}}{553} \times \frac{4300}{\text{static strength of welded specimen.}}$$

It should be noted that these ratios, based as they are on the doubtful assumption that the impact strengths of similar welded joints is proportional to their static strengths, are probably only roughly approximate.

On behalf of himself and Mr. Weeks, the writer takes this occasion to acknowledge with thanks the generosity and courtesy of the Vilter Manu-

facturing Co., and of the General Boilers Co. who donated specimens and made many helpful suggestions as to their design.

TABLE I

RESULTS OF STATIC TESTS ON LAP-JOINTS WITH FILLET WELDS

Specimen	Thickness of Plates, In.	Average Breaking Strength of Welds: Lb. per Sq. In.	Max. % Var. from Mean	Lb. per Linear In.	Max. % Var. from Mean	Average Elongation in Inches	Average Yield Point, Lb. per Sq. In.
1, 2, 3	1	16,800	6.6	17,220	13.8	0.12	14,700
4, 5, 6	1/2	25,000	3.2	12,100	4.8	0.15	19,270
7, 8, 9	1/4	31,130	7.3	8,200	9.8	0.13	20,250
10, 11, 12, 13..	3/4	29,175	5.2	11,050	8.6	0.14	25,600
14, 15, 16, 17..	1/4	28,050	13.0	7,300	2.0	0.14	25,700
18, 19, 20, 21..	1/4	(Failure occurred in welds of only one specimen)					

Note: Length of specimens 1 to 9, inclusive, about 1 in.; specimens 10 to 17, inclusive, exactly 1 in.; specimens 18 to 21, about 2 in.

TABLE II

RESULTS OF STATIC TESTS ON BUTT JOINTS WITH FILLET WELDS

Specimen	Thickness of Plates, In.	Average Breaking Strength of Welds: Lb. per Sq. In.	Max. % Var. from Mean	Lb. per Linear In.	Max. % Var. from Mean	Average Elongation in Inches	Average Yield Point, Lb. per Sq. In.
22, 29, 30	3/4	26,530	4.0	15,420	4.0	0.09	18,100
23, 27, 28	1/2	24,330	3.0	11,200	4.5	0.10	16,700
24, 25, 26	1/4	38,600	6.0	8,430	2.6	0.09	27,300
31, 32, 33	1/2	26,820	20.0	11,460	9.3	0.20	19,000
34, 35, 36	1–7/8	25,860	7.3	17,480	9.9	0.15	16,500
37, 38	5/8–1/4	33,000	2.7	7,075	2.5	0.08	25,500
39, 40	3/4–3/8	36,500	2.0	7,475	0.3	0.07	28,100

Note: Length of specimens 22 to 30, inclusive, about 1 in.; specimens 31 to 36, inclusive, about 2 in.; specimens 37 to 40, inclusive, exactly ½ in.

TABLE III

RESULTS OF IMPACT TESTS ON BUTT-JOINTS WITH FILLET WELDS

Specimen	Thickness of Plates, Inches: Main Plates	Splice Plates	Energy of Rupture in Inch-Lb.: Total	Per Sq. In. of Weld	Estimated Static Strength of Specimen, Lb.	Calculated Ratio of Impact Strength of Welded Specimen to Impact Strength of Riveted Specimen of Same Static Strength
1—I	5/8	1/4	1,010	5,150	5,980	1.31
2—I	5/8	1/4	736	4,550	4,830	1.18
3—I	5/8	1/4	832	4,750	5,340	1.21
4—I	5/8	1/4	1,155	6,540	6,330	1.42
5—I	5/8	1/4	1,452	8,120	6,400	1.76
6—I	5/8	1/4	1,470	8,000	6,580	1.74
7—I	5/8	1/4	1,510	8,400	6,440	1.82
8—I	3/4	3/8	1,510	7,150	7,850	1.49
9—I	3/4	3/8	(Defective specimen, results not recorded)			
10—I	3/4	3/8	461	3,940	4,180	0.86
11—I	3/4	3/8	598	4,540	4,720	0.98

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efficiency increased in all phases of work.) Job Welder Becomes Manufacturer. (Success of experimental welded pot for heat treating ribbon steel leads to fabrication on larger scale.) A Problem in Municipal Sanitation. (Artesian water supply protected against pollution by oxwelded castings extending nearly 300 ft.) One Thousand Pound Pressure Test. (Severe working conditions of water column for boiler calls for welded joints.)

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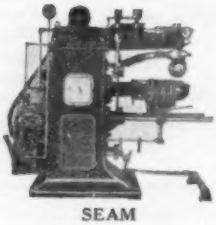

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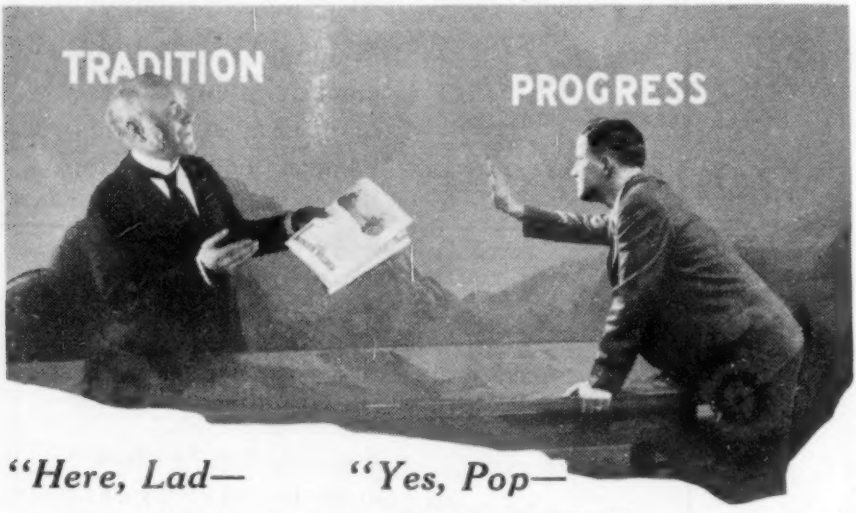


"Here, Lad—

I see where the automobile trade is preparing to meet stiff competition by modernizing plants. Thank goodness most of the equipment in our plant is pretty nearly new."

"Yes, Pop—

and there we STOP.

MODERNIZING doesn't necessarily mean the buying of new machinery or methods—to SPEED UP production and CUT DOWN costs without taking away from the quality of the finished product.

For instance, in our own work, where drilling and riveting takes time, weakens members and stamps our product as "old line production stuff"—we can 'Stable-Arc' weld it in far less time, make a stronger job and be in a position to meet competition.

And what is more, Pop, we can then not only meet it but walk away from it."

A new textbook on Arc Welding (Price $1.50) will be sent on approval for five days to any executive requesting it.

Book size, 6" x 9"—total pages, 160—number of illustrations, 200—Charts, 62—Divisions, 8.

The Lincoln Electric Co., Dept. No. 22-1, Cleveland, Ohio

"Stable-Arc" W-6

LINCOLN WELDER

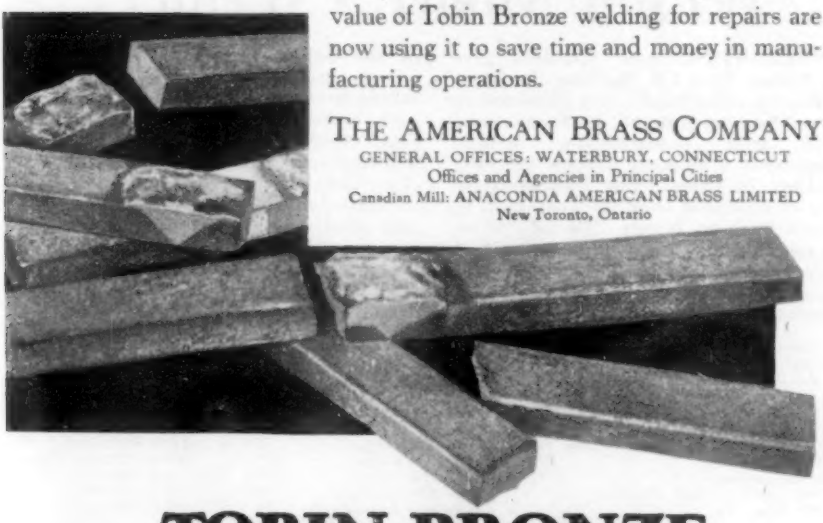
Mention the "Journal of the American Welding Society."

Strength Tests Prove: that cast iron, properly welded with Tobin Bronze, never fails at the weld

PERFECT samples of cast iron bars were cut in two, welded together again with Tobin Bronze, and subjected to straight pull strength tests. All failed in the cast iron—there were no failures in the bronze. In fact, Tobin Bronze would have resisted failure if the stress had been twice as great.

In addition to its strength, Tobin Bronze has the advantage of flowing freely at 1650°F. This low welding temperature usually eliminates preheating and dismantling, and minimizes distortion of the casting.

Many manufacturers who have proved the value of Tobin Bronze welding for repairs are now using it to save time and money in manufacturing operations.



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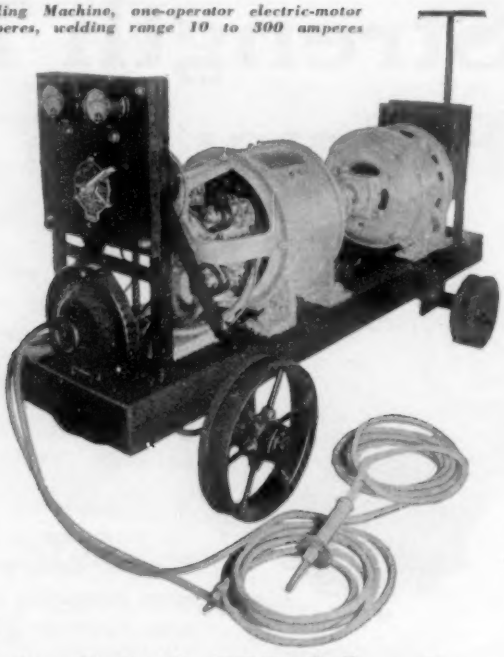
GENERAL OFFICES: WATERBURY, CONNECTICUT
Offices and Agencies in Principal Cities
Canadian Mill: ANACONDA AMERICAN BRASS LIMITED
New Toronto, Ontario

TOBIN BRONZE
REGISTERED U.S. PATENT OFFICE
WELDING RODS

EXCLUSIVELY AN ANACONDA PRODUCT

Wilson Model S Welding Machine, one-operator electric-motor driven, Type 200 amperes, welding range 10 to 300 amperes



New *and* Striking Features *in the* *Wilson Model S Welder!*

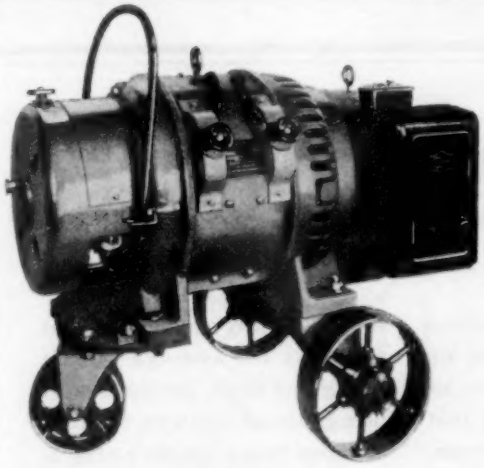
INTERESTING *new features* give the Wilson Model S Machine the highest degree of efficiency yet obtained in arc welding equipment. Its frame is of angle iron construction, welded throughout, and made narrow for easy handling in shops. The improved reactor is mounted over the rear axle to protect it from injury. There are no live parts on the front of the modified control panel. A new rotary switch, together with a new design of field rheostat, afford very fine adjustments of the welding current. Exceedingly close regulation is available for strength welding, while a long arc with heavy current is available for rapid depositing of metal. Close control and quick recovery make the machine ideal for overhead welding, and the standard machine welds the thinnest sheet metal that the electric arc can handle. The Wilson Model S Welding Machines are equipped to give full welding range without extra apparatus or extra cost.

One-operator	Motor	Generator	Set	Type 200 Amps.,	welding	range	10 to 300 amps.
One-operator	"	"	"	Type 300 Amps.,	"	"	15 to 500 amps.
Two-operator	"	"	"	Type 400 Amps.,	"	"	10 to 300 amps. or 300 to 600 amps.
Two-operator	"	"	"	Type 600 Amps.,	"	"	15 to 500 amps. or 500 to 1000 amps.
One-operator	Gasoline	Engine	Driven	Type 200 Amps.,	"	"	10 to 250 amps.
One-operator	"	"	"	Type 200 Amps.,	"	"	10 to 300 amps.
One-operator	"	"	"	Type 300 Amps.,	"	"	15 to 500 amps.
One-operator	Belt	Driven		Type 200 Amps.,	"	"	10 to 300 amps.
One-operator	"	"		Type 300 Amps.,	"	"	15 to 500 amps.

WILSON WELDER & METALS CO. INC., WILSON BLDG., HOBOKEN, NEW JERSEY

WILSON

WELDING MACHINES AND WELDING WIRE



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FUZON
ARC WELDER

A Welder So
Different
It Merits
Investigation

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K-G

means on
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K-G WELDING & CUTTING CO., Inc.
515 West 29th Street
Phone Chickering 0996-7-8 New York City

That "personal equation" in welding —*

THERE IS a widely spread notion that welded joints are satisfactory only if you have an unusually good welder and that such welders are rare as jewels.

Let us straighten out this idea once and for all. Good welders are necessary, but with proper supervision good welders can be developed in a comparatively short time. Here, for example, are test records of single vee welds made with high grade soft iron wire by an average student during the first months of his employment:

Month	No. of Welds Tested	Average Tensile Strength
June, 1926	4	22,000
July	3	39,000
August	5	44,000
September	4	49,000
October	3	49,400

And when it is remembered that 47,000 is the average tensile strength of single vee joints with high grade soft iron wire, it can be assumed that a welder having a reasonable training period, working under proper shop conditions and competent supervision, would be able to turn out work meeting any reasonable specification.

If you exercise the same kind of care in purchasing or manufacturing welded equipment that is customary in purchasing machinery, and if you select the shop or the welder properly, you can rely on welded construction.

THE LINDE AIR PRODUCTS CO.
Unit of Union Carbide and Carbon Corporation
General Offices: Carbide and Carbon Bldg.
30 East 42d Street, New York
37 PLANTS · · · · · 107 WAREHOUSES

LINDE OXYGEN

* No. 3 of a series of advertisements on the engineering phases of oxy-acetylene welding and cutting. Send for the booklet entitled: "Engineering and Management Phases of Oxwelded Construction."

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Oxweld C-14 cutting blowpipe

IF YOU are perfectly satisfied with your cutting blowpipes, don't ask to have the C-14 demonstrated.

Because—

Every time this new member of the Oxweld family is demonstrated, it makes a convert.

It has all the inherent advantages of the Oxweld injector type blowpipe.

It can be used with either low or medium pressure acetylene. And you can't make it back-fire.

OXWELD ACETYLENE COMPANY

UCC

Unit of Union Carbide and Carbon Corporation

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STOCKS IN 41 CITIES

IN CANADA, Dominion Oxygen Company, Ltd., Toronto

Oxweld

WELDING AND CUTTING APPARATUS

Mention the "Journal of the American Welding Society."

Uniform Quality Carbide

THERE is a real and thoroughly practical reason back of the statement that Union Carbide gives the highest uniform gas yield.

It is this.

No matter how carefully production is controlled, there is some variation in the grade and sizing of carbide. But only the highest quality carbide, that which conforms to most rigid specifications, is shipped to Union Carbide customers in blue and gray drums.

The Union Carbide Company has extensive and unrivaled facilities for using that carbide which doesn't conform to blue and gray drum carbide standards.

This means that Union Carbide customers get only the carbide with the highest uniform gas yield It means that every pound of Union Carbide, packed into the blue and gray drums, will give the user greatest return on his invest ment.

UNION CARBIDE SALES COMPANY

Unit of Union Carbide and Carbon Corporation

UCC

Carbide and Carbon Building, 30 East 42d Street, New York

Peoples Gas Building, Chicago, Ill. *Adam Grant Building*, San Francisco, Cal

UNION CARBIDE WAREHOUSES IN 190 CITIES

UTILITY

A useful product is not just a happening but the result of years of patient, careful effort. Prest-O-Lite dissolved acetylene has been on the market for twenty-three years, with an ever-increasing volume of sales. That is proof of utility.

THE PREST-O-LITE COMPANY, INC.

Unit of Union Carbide and Carbon Corporation

General Offices: Carbide and Carbon Bldg., 30 East 42d St., New York

31 Plants—102 Warehouses

Prest-O-Lite

DISSOLVED ACETYLENE

Mention the "Journal of the American Welding Society."

Three Master Welders

A COMPLETE line of Westinghouse welding sets are now available —distinct types of single operator machines for each class of work—with ratings of 200, 300 and 400 amperes.

These sets represent the latest development in welding machinery. The entire range of each machine is obtained by merely turning a single rheostat handle. They are all equipped with Linestart Motor and Linestarter —a simple and economical combination.

The generator responds instantly to any change of voltage in the arc. The design of the Westinghouse welding generator assures a fast and dependable machine—one that assists the operator to do more and better work.

Westinghouse Electric & Manufacturing Company,
East Pittsburgh, Pennsylvania

Sales Offices in All Principal Cities of the United States and Foreign Countries

Westinghouse

INDUSTRIAL GASES

I.O.C. SYSTEM

Engineering Service: Installation of Complete Oxygen and Hydrogen Plants and Gas Distributing Systems.

KNOWLES ELECTROLYTIC PLANTS FOR PRODUCING HYDROGEN

Knowles Patented Cells are safe, simple, easy to install, automatic, low in first cost and maintenance. All sizes up to 15,000 amperes.

Cutting and Welding Equipment: EYEOSEE and INTERNATIONAL cutting and welding torches, regulators, acetylene generators. The best built, most efficient and economical line made.

Supplies and Accessories: I. O. C. patented packingless high-pressure valve, safe and easily operated. Complete line of supplies for Gas Plants and Welding Shops—oxygen testing sets, charging lines, goggles, asbestos gloves and mats, welding rods and wire.

OXYGEN
ACETYLENE
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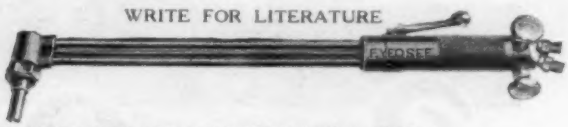
NITROGEN
PRIMOGAS

WRITE FOR LITERATURE



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OXY-ACETYLENE EQUIPMENT

Gives more satisfactory service. Operates with a lower gas cost. Costs less to maintain *than any other equipment*—

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IN WORKMANSHIP
WHERE
SKILL AND GOOD TOOLS MEET.

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glare proof welding glass

Made from a special glass that FILTERS the GLARE, producing a softer and more comfortable vision.

ESSENTIALITE LENSES ARE SCIENTIFICALLY CORRECT, for Electric Welding there are none better—they positively aid in conserving the eyesight of those who are subjected to welding glare.

Manufactured by
CHICAGO EYE SHIELD COMPANY
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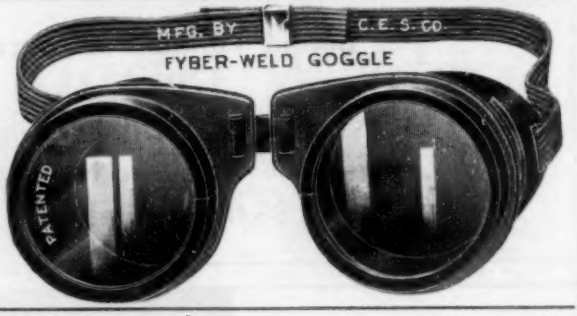

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Catalog 54?

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Baltimore, Md.

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Proven, inexpensive, practical, and simple in its application to all classes of work involving the repair of medium and heavy size sections of iron and steel.

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That welding wire test *did pay!*

—as told by a man who made one

"Welding wire costs do not stop with the purchase of the wire. With the high prices we are paying expert welders now it does not take many bad pieces of wire to waste a lot of dollars in time.

"Then you must consider the investment in the finished article being welded. A fraction of a per cent of spoiled work or even poor work may more than equal the total cost of the welded wire used.

"We have found the best welding wire we can buy is the cheapest we can use because it saves expensive time. That is why we standardize on Page-Armco since we made our tests."

You can test Page-Armco Welding Wire in your own job. Your name and address will bring samples.

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PROCESSED

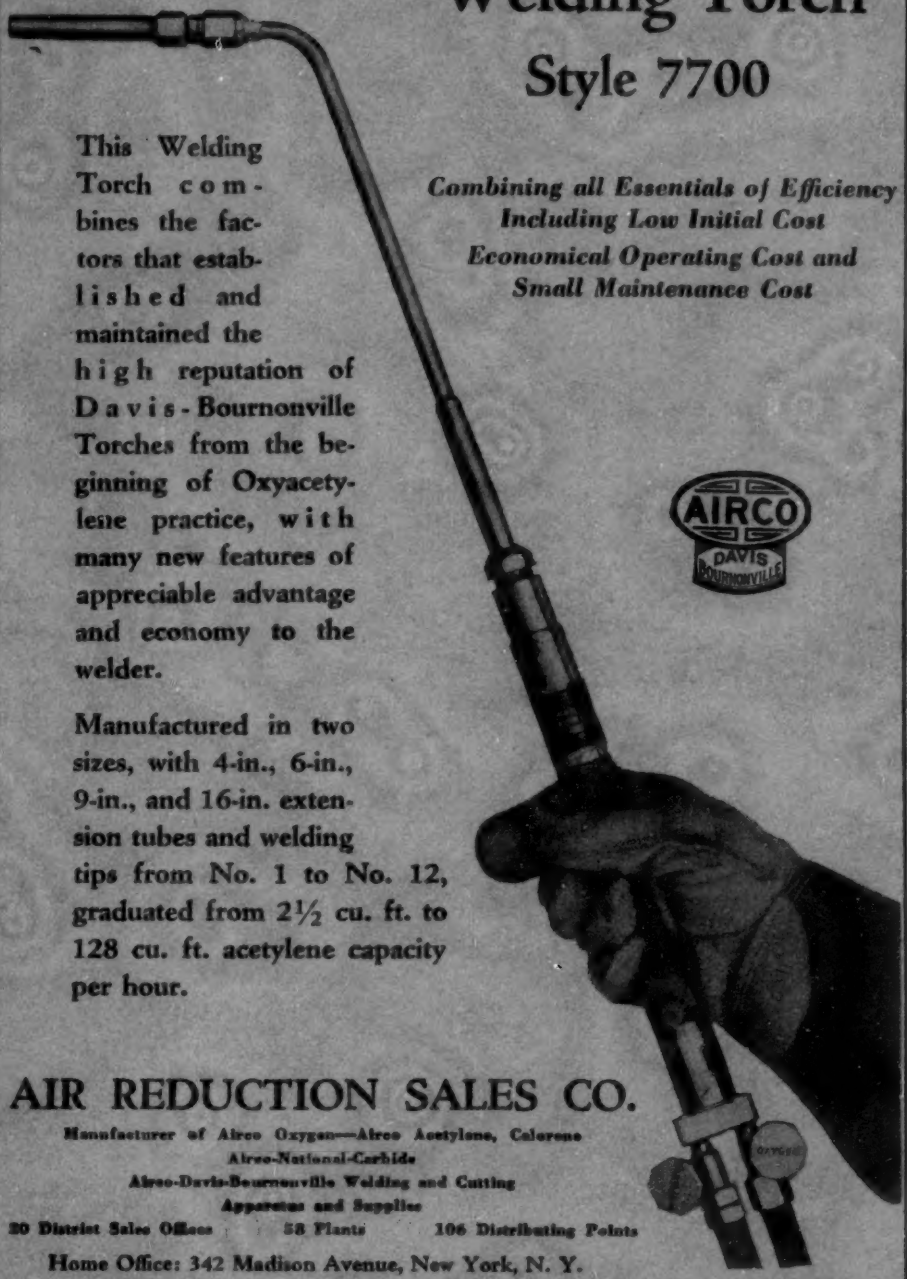
Welding Wire *and* Electrodes

An Airco-Davis-Bournonville

Welding Torch

Style 7700

Combining all Essentials of Efficiency
Including Low Initial Cost
Economical Operating Cost and
Small Maintenance Cost



This Welding Torch combines the factors that established and maintained the high reputation of Davis-Bournonville Torches from the beginning of Oxyacetylene practice, with many new features of appreciable advantage and economy to the welder.

Manufactured in two sizes, with 4-in., 6-in., 9-in., and 16-in. extension tubes and welding tips from No. 1 to No. 12, graduated from 2½ cu. ft. to 128 cu. ft. acetylene capacity per hour.

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